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Industrial QUALITY CONTROL

Vol. XIV, No. 11
MAY, 1958

QUALITY
through
Scientific Methods

Journal of the
AMERICAN SOCIETY FOR QUALITY CONTROL

Checking circularity of valve components at the Eli Whitney Metrology laboratory

DIAGNOSIS and TREATMENT of Servo Valve Disorders

After wrestling diligently with the problem of slippage or leakage, an aircraft servo valve manufacturer turned to the Eli Whitney Metrology Laboratory for help. Scrap rate had climbed to 50% and deliveries had become critical.

A precise laboratory analysis for geometrical values revealed not one but three defects—all slight but nevertheless potent.

1. A washed out condition in the sleeve bore around the ports
2. piston lands lobed
3. land surfaces too rough for this type of service

This analysis indicated the necessity for changes in processing. These were made and scrap rate dropped immediately from 50% to 4%.

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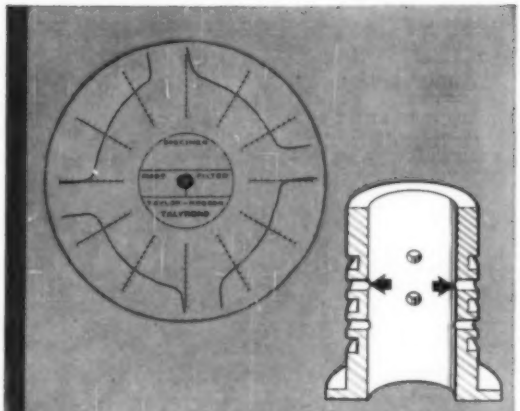
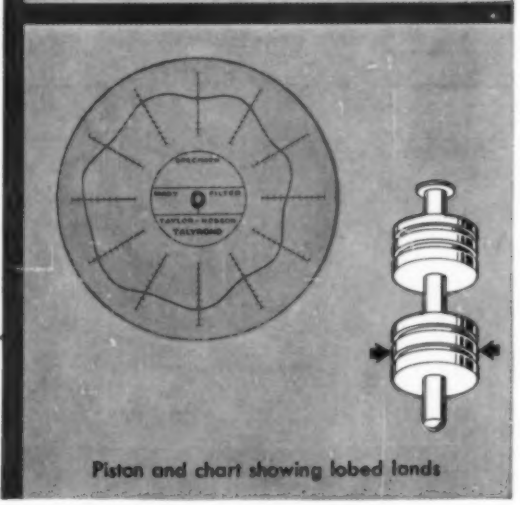


Sleeve and chart showing condition at the ports



Piston and chart showing lobed lands

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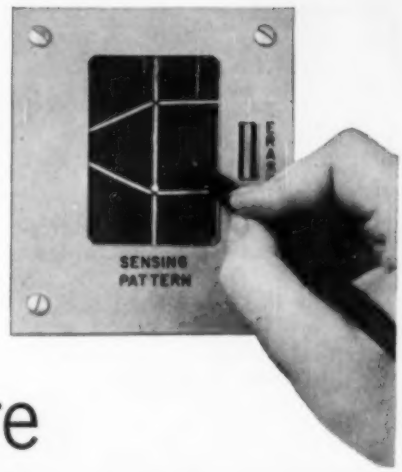

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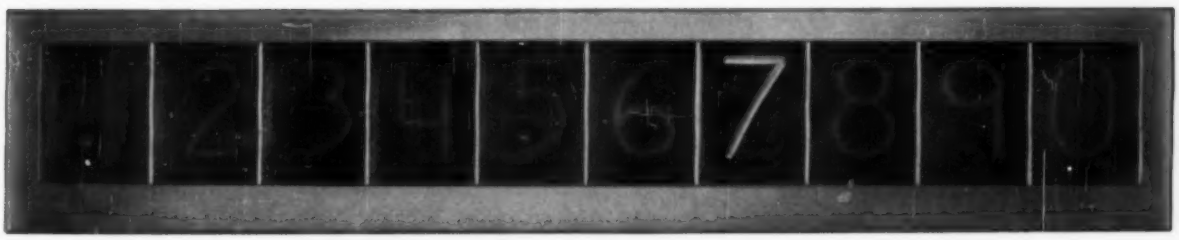

on new Bell Labs machine

A new device invented at Bell Laboratories "reads" a numeral while it is being written and instantly converts it into distinctive electric signals. The signals may be employed to make a numeral light up in a display panel, as above, or they may be sent to a computer or to a magnetic "memory" for storage.

The writing is done with a metal stylus on a specially prepared surface. Two dots, one above the other, are used as reference points. Seven sensitized lines extend radially from the dots. Transistorized logic circuits recognize numerals according to which lines are crossed.

The concept of a number-reader has interesting possibilities as a new means of communication from humans to machines. For example, in an adjunct to a telephone, it might provide inexpensive means of converting handwritten data into signals which machines can read. The signals could be transmitted through the regular telephone network to a teletypewriter or computer at a distant point. In this way, a salesman might quickly and easily furnish sales data to headquarters, or a merchant might order goods from a warehouse.

Tom Dimond, a B.S. in E.E. from the University of Iowa, demonstrates an experimental model of his number-reading invention. A similar device can also be made to read alphabetical characters. Small size and low power requirements result from transistor circuitry.

Modern communication involves many more fields of inquiry than the transmission and reception of sound. The experimental number-reader is but one example of Bell Telephone Laboratories work to improve communications service.

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INDUSTRIAL

Quality Control

Vol. XIV, No. 11 May, 1958

Contents

ARTICLES

Reliability and the Quality Control Engineer
Robert G. Fitzgibbons 13

Sampling of Paper and Paper Products
George G. Maltenfort and R. E. Boedeker 19

"Egg-Crate" Sampling—A Key to Higher Quality on Low Quantity Production
William R. Baker 24

The Teaching of Statistics and the Training of Statisticians for Industrial Employment
Carl E. Marshall 28

Instrument Calibration Scheduling Simplified With Electronic Data Processing Machines
W. A. Lawrence 32

Quality Control as an Administrative Aid
Charles A. Bicking 36

A Mechanical Variables Sampler
Joseph Albert Greenwood 44

DEPARTMENTS

From the President's Desk, *Consumer Product Quality Control* 12
Twelfth Annual Convention 40-41
From the Scrap Box, *Other Staff Groups Can Use Statistics Too!*
S. Reed Calhoun and Paul E. Green 48
What's New? 52
Book Reviews 60
Section Briefs 60
Section Calendar 66
List of Short Courses in Quality Control 70
Product Education Service 75
Report of the Examining Committee 75
Clinics, Conferences, and Courses 75
Positions Available 76, 77
Positions Wanted 76
Consulting Services 76

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from drawing board to shipping dock

Statistical quality control is one of those "behind-the-scenes" functions in industry of which, as such, the general public is seldom aware. Often, even the salesmen of a firm, to whom quality is so important in a product, are not aware of how methodically quality in the successful firm is policed and maintained.

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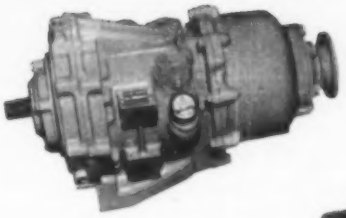
QUALITY

from start



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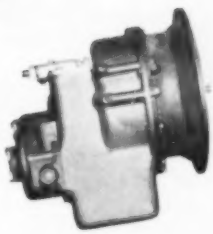

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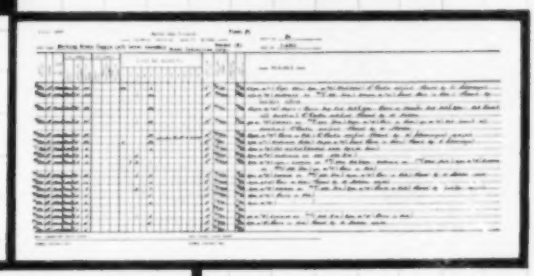

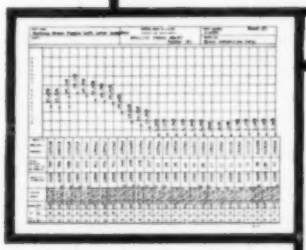

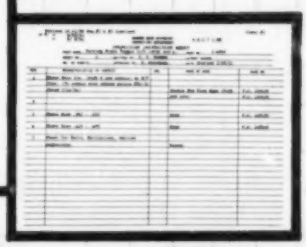

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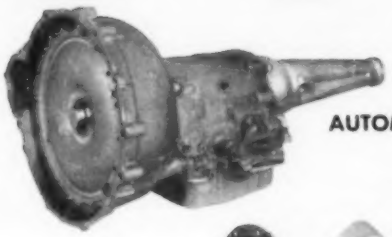

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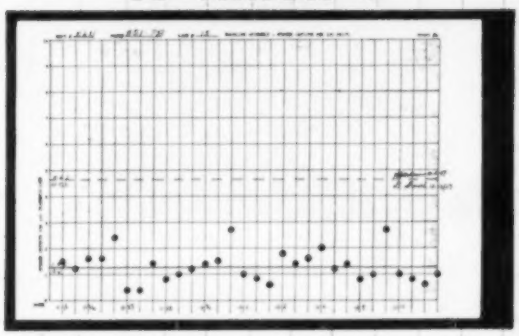

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From the President's Desk

Consumer Product Quality Control

Quite recently the ultimate consumer has started to take a direct interest in Statistical Quality Control. Just as eating proves the pudding, the ultimate consumer will judge the value of SQC on the criterion of how effectively it has provided more goods at lower cost.

The consumer thus raises some of the usual quality control questions with respect to SQC itself. How can these powerful methods of evaluation and analysis serve the consumer more adequately? Can the methods of SQC be utilized by the consumer agencies in the evaluation of better quality? Can verifiable quality information supplement his pecuniary considerations in making choices in the market? Can the use of quality control standards eliminate inferior furniture or unsafe electrical appliances from the market?

Not that the consumer interest has gone entirely unconsidered in the past. The difference is that many have spoken for him indirectly. The Quality Control and Quality Assurance Departments in many companies, for instance, have considered themselves vested with the consumer interest. Acceptance inspection groups in buying organizations, in department stores, mail order houses, and the military services, have also identified themselves with the consumer. On a lower key, the fair trade groups, food and drug administrations and the like, legislated into protection of consumer health and safety, have employed SQC methods on behalf of the consumer. Moreover labor unions, the American Home Economic Association, and organized consumer groups have considered themselves spokesmen for consumer quality.

Whether all these voices can be unified or whether the ultimate consumer will take an independent viewpoint is a matter of conjecture. This was the subject of a conference on "Quality Control and the Consumer" held at Rutgers University last fall.* There the Vendor-Vendee Committee and the Textile Division of ASQC along with Consumers Union and Rutgers University sponsored an exploratory session. Several ways of implementing consumer action in quality control usage were suggested. One of these had to do with the furnishing of realistic quality information by the producer to the ultimate consumer, and a feed-back system to the production activities. Another suggested consumer usage of SQC involved the establishment of consumer goods standards together with industry-wide quality policing agreements such as those used in the Avisco seal of approval. A third approach considered the development of a consumer products specification akin to MIL-Q-5923, RIQAP AND CIGAIP, the military standards for assuring quality controlled manufacture. The Swedish method of government and industry cooperation in the labeling and verification of quality standards of consumer goods was also discussed.

It is always good to hear of a new and important interest in SQC. It is especially good in this case, not merely for the large numerical strength that the ultimate consumer may muster into conscious SQC interest, but also because of the new dimension that the ultimate consumer may give to SQC thinking. This new interest may keep us all reminded of our goal of "better products at lower costs to the consumer through Quality Control."

Sincerely,

Leon Bass

*Editorial Note. "Quality Control and the Consumer" as reprinted from *Consumer Reports* appeared on page 28 of the April issue of *Industrial Quality Control*.

Reliability and the Quality Control Engineer

ROBERT G. FITZGIBBONS

Bendix Products Division—Missiles, Bendix Aviation Corp., Mishawaka, Ind.

The purpose of this article will be to acquaint the reader with a new field of industrial endeavor called *Reliability*. In this article I will do my best to review the reasons for such a new field, to explain something of its methodology, and to describe in what respects it is similar to, and in what respects it is different from quality control.

The material to be presented will contain little information new to those working in reliability. Rather the intention is to describe reliability in general terms to those who have not been closely connected with it.

Since my own experience in reliability has been restricted to the problems of reliability in guided missiles, all of the material presented in this article will be from the point of view of this industry. My experience has been with the Reliability Group of the Bendix Products Division—Missiles Section, a reliability activity that has been in existence for approximately two and one-half years. Bendix is the prime contractor to the Navy Bureau of Ordnance for TALOS, a surface-to-air guided missile, and this Reliability Group has made a significant contribution in achieving the present reliability position we now have.

What Is Reliability

As a point of departure let's start with a generally accepted definition of reliability written by Dr. Richard Carhart of the Missile Division of Lockheed Aircraft.

> *"Reliability is the probability that a device, equipment, or system will perform its intended function for a specified period of time under given conditions."*

We can go a long way toward seeing the need for a specific reliability effort by examining the reliability definition. We see first that reliability is a probability and we suspect from this that we will not have certitude that our device will always function perfectly. Why can't we have such certitude? The primary reason is the complexity of today's weapon systems.

Complexity

Guided missiles as we know them today can have as many as 10,000 electronic parts (and there may be some I don't know of that have even more.). Compare this with your TV set which has about 250 electronic parts. Even as well as your TV set has been engineered, on occasion it will experience what is referred to as a "random component failure." In other words electronic parts don't last forever and even the best of sets will ultimately require some maintenance.

Most electronic equipment is designed on a series principle. That is, the parts may be considered to be links in a chain such that the failure of one part or link results in the failure of the chain or the system. It can thus be seen that there is some relationship between complexity and reliability. Although we don't know exactly what this relationship is, since an electronic system is not exactly like a chain because some links in the electronic chain are parallel or "have redundancy," nevertheless, there exists what we call a "trade-off relationship" between complexity and reliability. In other words an increase in system complexity will generally result in decreased system reliability.

With the unbridled tendency toward increased complexity resulting from the increased design demands on new electronic systems it then becomes a problem to keep such systems going not for hundreds of hours as with TV sets but for only a few minutes in the case of guided missiles.

It goes without saying that reliability poses a problem very important to solve. The mission of a surface-to-air missile is to defend a ship or a city from attacking planes or missiles. It can be seen that every missile must possess a high degree of reliability when the chips are down. Few duds can be tolerated. Not only is it important that a missile possess a high degree of reliability in tactical use, but it is also important that it hold up prior to tactical use. One of the primary reasons the services have pushed for the reliability of electronic gear is the high cost of maintaining such equipment in the field. A study has shown it costs about ten times the initial cost of a piece of gear to maintain it throughout its life in the field. It was therefore thought wise by the military to spend money in the early stages of design and production of an equipment to enhance its reliability.

Let us look at another portion of the above reliability definition to gain additional insight into reliability: *"Under given conditions."*

Environment

The phrase "under given conditions" in the reliability definition is deceptive. It's easy to say but it's usually said with tongue in cheek. If we are asked the simple question "under what conditions will your missile fly—what is the missile environment?", we don't have all the answers.

If you are designing a product for commercial consumption, you can

obtain knowledge of the environment it will experience in use through a survey, or by placing several samples in actual use for a trial period. If the unit fails it will usually be possible to determine the exact mode of failure.

With missiles and other electronic equipment the problem is much more difficult. Designers are operating at the frontiers of knowledge in determining missile environments. The basic knowledge of environmental conditions at high altitudes and speeds is still sketchy. One of the basic environments which a missile experiences is vibration. Although there has been a great deal of study on the nature and effect of vibration, there is still a lot to be learned.

Since a missile is a complex thing, complete knowledge of how the missile environment is transmitted to its components takes a long time to obtain. For example a missile may experience vibration of a given frequency and amplitude on its exterior and transmit far more than this to its components inside through an effect referred to as "oil canning."

Although it would be tremendously helpful to know the environment each component part of a missile experienced in flight even this would not be the entire answer.

When a man designs a bridge he computes the *stresses* that each member will experience, then using tables that tell him the *strength* of the materials he is using he assures himself that his design possesses a high safety factor. It appears that we must know the inherent strength of each of the electronic parts in withstanding our environmental stresses. The desire to know component strengths has led some companies to embark on extensive "test to destruction" programs. In such testing programs components are subjected to ever increasing stresses until they fail. Knowing the stress each component sees in flight, and the strength of each component to withstand each stress you would know a lot about the missile. Actually, even this wouldn't be the entire story since you would also need to know a great deal about the interactions of all missile parts and their applied stresses.

To summarize these points, in most instances if you are designing a product for commercial use, it is possible to compute or determine the stress such a product will experience, and knowing the strengths of the materials to be used, it is possible to design and build a product that will last indefinitely. (That this is not done results from such counter factors as cost, competition, and market saturation).

On the other hand, if you are designing a missile, the following problems occur:

1) You don't know the stresses the missile will experience in use. Missiles go fast and high and experience many stresses and strains in the process. Designers are operating at the frontiers of knowledge in determining missile *environment*.
2) You don't know the strengths of the ingredients you are putting into the missile. In other words, you don't know how much stress each part will take before it fails.
3) And thirdly, if you did know just how much each part would take, and you did know the missile environment, there are so many parts that you would have a very difficult time determining just how all these parts together would withstand the applied stress to the missile.

The third portion of the definition we shall examine is *"its intended function."*

Task

In general the task or purpose of most commercial products is fairly specifically defined. For instance if we have designed a letter opener to open letters, we then don't expect to be able to use this to open tin cans, or carve steaks. On the other hand in the rapidly changing technological era in which we live "the intended function for which it was designed" is constantly changing. In the case of guided missiles the question often asked after a design is completed is "Will it go a little higher, faster, or farther?"

Recently the Department of Defense has been tending toward reliability specifications. Such specifications say, in essence, that before a manufacturer can go into production on a prototype unit, he must demonstrate at an X percent confidence level that his product is Y percent reliable. Such specifications will necessitate a fairly explicit statement of intended function.

Poor Definition of Flight Defects

There is another reason for a specific reliability effort which is not obvious from an examination of the reliability definition. This reason is the lack of explicit information on *how* missiles fail in flight.

If you are a manufacturer of a commercial product and the product doesn't perform satisfactorily in the field, the customer will probably make a very specific complaint. Such a complaint will be transmitted by the sales people to the engineering department which will initiate a design change.

However, if you are a missile manufacturer, the nature of the complaint you get from the customer is likely to be "it doesn't work." This is because almost all missiles are one shot in nature and end up as a charred heap after flight. True, certain information is "telemetered" or radioed back from the missile during flight but such data only broadly defines the trouble spot within the missile. For this reason a more than normal importance is placed on testing conducted in the factory. Such test results must be relied on in the main to detect design inadequacies.

The Weapons System Concept

Still another reason for a specific reliability activity is the advent of the weapons systems concept. Many of the weapons being designed today are so complex that no one plant possesses either the engineering or manufacturing facilities to design or produce them. To quickly get such systems into production it has been necessary to devise a plan known as the weapons systems concept whereby one company is given the prime contract for the weapon and this company in turn subcontracts major portions of the system to other agencies for design, manufacture, or both. It is therefore common for the design, manufacture, and testing of a system to take place over a large geographical area. Such diversified effort requires a co-ordinated reliability effort.

Reliability Modus Operandi

To date there have been many articles and papers on the subject of reliability. So far the entire subject of reliability is rather fragmentized. You will see articles on the reliability of tubes, relays, transistors, and connectors. You will see articles on testing to destruction, combined environmental testing, and the effect of vibration. You will see articles on designing for reliability, predicting reliability, testing for reliability, organizing for reliability, redundancy, failure data collection systems, flight test simulation, and reliability education. Reliability is a new area of endeavor and is still in the formative stages. For the moment we will step

back from the trees and try to see the forest.

In its broadest aspects relability is concerned with the design of a product and the execution of that design. It is thus an all-encompassing activity in a given program. It is *so* all-encompassing that it can't be the private domain of any one group in the plant. This has led to the slogan at Bendix that "Reliability is Everybody's Business."

There are thus two aspects to reliability. One of these we can call "before the fact reliability," the other "after the fact reliability."

Before the Fact Reliability

"Before the fact reliability" gets reliability into the design. Henry Ford once said "Quality begins on the drafting board." Just as quality begins on the drafting board so reliability begins with the initial systems planning. As mentioned before there is a trade-off relationship between complexity and reliability and an optimum combination of mission and reliability is important. There should therefore be reliability studies made in the very first aspects of design.

There are many people today who believe that reliability is a design parameter, and that it is possible to predict the reliability of a design before ever making or testing it. They believe that from failure data gathered from previous programs, it is possible to extrapolate and predict the reliability of new systems. They view reliability as analogous to a weight and balance specification. Thus, if a missile has an over-all reliability specification and is to be sectionalized into several large assemblies, they feel a Reliability Group will act as does a Weight and Balance Group and say to the engineer who has designed an assembly, "go back and redesign it. You have used up more than your share of unreliability." Personally, I feel we have not reached this state of skill as yet, but I feel we will reach it soon.

Since I am not a design engineer I am not equipped to tell you all the methods a design engineer will employ to make his design reliable. He will certainly find out all he can about the environment his design must encounter. He will want a specific statement of task. He will use only component parts of proven quality from vendors of known integrity. He will utilize feedback compensating loops and redundancy wherever he can and will package his device to protect it from all environments to the best of his ability. He will employ "safety factors" wherever he can and "derate" as many components as he can. He will run extensive tests on the first breadboard and prototype units. He will design his equipment in modular form so that each module is functionally replaceable and integrally testable. As his unit then moves into production and later goes through field evaluation and then tactical use he will follow the factory and field testing of his design and correct any design deficiencies that show up. He will utilize the experience gained in one program in designing for the next.

After the Fact Reliability

"After the fact reliability" is that effort expended in seeing that a design is properly executed.

A good reliability design for a missile does not guarantee that it will prove to be reliable in use. There is still the other side of the coin which we have called "execution." No matter how good the design is, if it isn't properly manufactured and tested, it will be unreliable in use. Achieving reliability in use must therefore be a team effort involving everyone in a program.

Mark Twain once said "The man who can read and doesn't is no better off than the man who can't read." Similarly the missile that is well designed but not properly executed is no better off than the missile that is poorly designed.

The "after the fact" approach to reliability has been termed the "wonderful one horse shay" approach. In this approach, the intention is to see that all components are failing randomly—that is, that none of the parts of a given class are failing at a significantly high rate. Then with all parts failing at about the same rate, the missile, like the shay, would fall apart all at one time.

In this approach to reliability, a Reliability Group serves as a central intelligence agency collecting data on failures and discrepancies of all kinds. These data are examined and distilled and significant conclusions are fed back to Engineering, Quality Control, Manufacturing, and all parties concerned.

As mentioned above, reliability is such an all-encompassing thing that probably no one group in a plant can handle all aspects of it, particularly since it infringes on operations which are quite divergent as to function. As a practical example of how a company can cover the entire reliability area, I will describe the reliability program at Bendix Missiles Division.

Bendix TALOS Reliability Program

As prime contractor for the TALOS surface-to-air guided missile, Bendix acts as a systems co-ordinating group for a large subcontractor effort. In this effort Bendix acts as the hub of an operation that is quite diversified in location.

Within Bendix Missiles itself the plant is organized as in Fig. 1.

For the purposes of this article only the Engineering and the Qual-

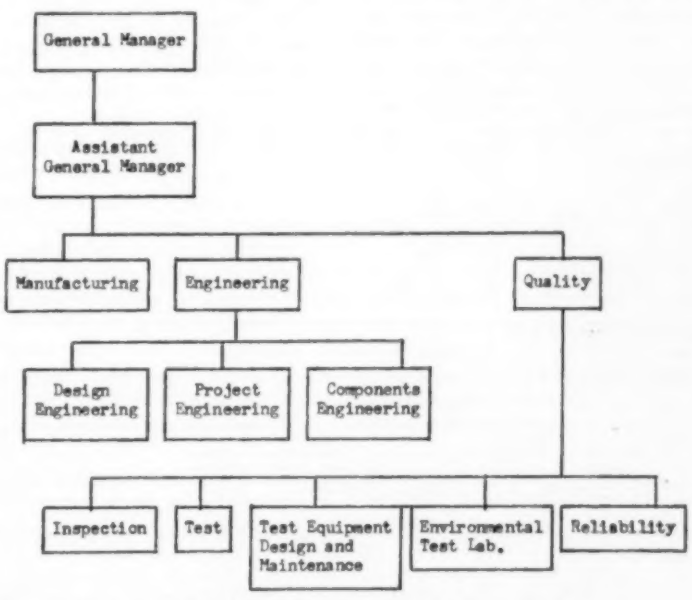

Figure 1—Bendix Missles Organization as it Relates to Reliability

ity Departments are shown in some detail.

At Bendix, the reliability approach is a team effort primarily between Engineering, Manufacturing, and Quality.

In any company there is a diversity of opinions conditioned by organizational position. Thus Manufacturing has a tendency to be influenced by schedules, Engineering has a tendency to devote its attention to forthcoming designs and even Quality is not immune to the considerations of schedules and expense in considering the action to be taken in the correction of a known hazard. The management at Bendix has considered these matters and established one group which is concerned only with reliability. At Bendix the group is called the Reliability Section and it is organized under the Quality Department as it was felt this was the place from which it should operate. The only ax this group has to grind is reliability. This creates a check and balance system in which a note for reliability is always sounded. Other considerations may drown out that note on occasion but at least the reliability aspects of all problems are presented. By no means does this group have the reliability market cornered at Bendix.

When the Reliability Group was being organized at Bendix, it was decided to create a staff group rather than a line group. It was not the intention of our management to create a group that would approve designs from the reliability standpoint. It was felt that with the existing shortage of design engineers they should all be busy designing. Nor was it the intention to create a group that could tell anyone to do anything. It was the belief that everyone at Bendix wanted reliability and would do everything possible to achieve it if only shown where the weak spots were.

Feed Back on Bendix-Mishawaka
TDR # (If Applicable)
Discrepancy
Date
TDS #
System, Package, Module, or Major Item of Equipment
S/N
Mfr.
Type
Unit, Chassis, Sub-Module, or Sub Assembly
S/N
Mfr.
Part Name
Circuit Symbol
Vendor
Part Number
Date Code
S/N
WHERE DETECTED (Stage of Production)
Receiving Inspection or Test
Assembly or Fabrication
Unit Test or Sub-Module Test
Line Inspection, Sta. #
Other (Describe)
Module Test
Sub-System Test
Package Test
System Test
HOW DETECTED (Operation in Progress)
Visual Check
Continuity Check
Static Test
Vibration Test
Run #
Vibration
Shake # Freq.
Plane G's
Calibration
Trouble Shooting
Test Procedure
Other:
Electrical Operating Time (Hrs.)
On-Off Cycles
SYMPTOMS (First Indication of Trouble): Visual Other Explain and Give Readings
DESCRIPTION OF TROUBLE (Applies to the PART unless otherwise noted)
Open Circuit
Shorted
Broken
Gassy
Loose
Missing Part
Intermittent
Noisy
Erratic
Arcing
Foreign Material
Changed Value
Low Gain
Other - Explain
DETAILS AND REMARKS:
UNDERLYING CAUSE OF TROUBLE (If known)
Workmanship
Defective Part
Engineering
Secondary – Explain
DETAILS AND REMARKS:
IMMEDIATE CORRECTIVE ACTION
Repair
Replacement by
Part S/N
Tailoring
No Action
Other
DISPOSITION OF REMOVED PART OR UNIT
Re-Installed
Sent to
For Evaluation
No Removal
DID ACTION TAKEN CURE TROUBLE? YES NO UNKNOWN
Written by:
Reviewed by:
Date:
Bell RELIABILITY DEPT. USE ONLY
Serial No.
Cause
Responsibility
Action TDR
FCA Requested
Reviewed by
Date

Figure 2—Bendix-TALOS Discrepancy Report Form

The job of this group is to monitor, measure, and feedback to appropriate departments missile reliability. Let me go into some detail on our duties and responsibilities.

The duty of the Reliability Group at Bendix is to monitor the quality of the TALOS Missile and its test equipment for the purpose of *attaining* and maintaining missile reliability at required performance levels. This monitoring is accomplished by means of a common discrepancy reporting form shown in Fig. 2 which is used throughout the program, as well as by personal contact and follow up by reliability engineers in all phases of production, test, and inspection. The reliability effort includes a critical appraisal of design engineering, production methods, and test and inspection procedures. The over-all operation entails the following activities:

a) Comprehensive collection of all raw data relating to missile quality and reliability.
b) Tracing failures to their source and establishing the causes thereof.
c) Statistical analysis and reliability evaluation of all discrepancy and failure data as well as statistical planning of special reliability tests.
d) Feedback of significant conclusions to cognizant operating groups as well as follow up to determine the nature and extent of corrective action by operating groups.
e) Review of procedures of all operating groups in the missile program that may effect quality and reliability.
f) Collaborating with quality assurance groups of the Bureau of Ordnance, its technical advisors, and major associated missile program subcontractors, and study of reliability efforts in other related programs of the Bureau of Ordnance. Exchange of reliability information with other agencies and their contractors operating on other missile programs.
g) Establishment of a reliability education and information service for the TALOS program to serve all interested groups. This includes the production of motion pictures on reliability and quality.

Obviously, reliability is a team effort at Bendix. Missile design is the responsibility of Design Engineering but they use the failure information collected by the Reliability Group to

make their designs better. The Components Engineering Group is responsible for finding new and better piece parts for the missile, and for running special tests on parts which are thought to be reliability hazards. This group utilizes the failure data compiled by reliability to tell them which parts to test and the services of reliability statisticians to plan and evaluate their tests.

On the other hand reliability engineers deal with components engineers and design engineers on problems occurring in tests to insure that reliability hazards are known and corrected. Reliability engineers also work with Manufacturing, pointing out reliability hazards in processing.

Reliability engineers monitor reliability and quality from the Incoming Inspection Departments of our major subcontractors through the flight testing of our missile at White Sands Proving Grounds.

Although our Reliability Group has no direct authority, this is not to say we carry no weight. The management of Bendix has continually emphasized missile reliability to the extent that it is now thoroughly engrained into the thinking of everyone in the missile program. For this reason all of our recommendations are carefully considered and almost all are adopted.

It will be seen that to a great extent the success of a group such as ours will be based on the respect we have earned from other groups. The past activities of our reliability engineers have gained a high degree of respect around our plant.

Similarities and Differences of Reliability and Quality Control

Thus far you may have been thinking "Well, how is this any different from quality control?" Although reliability is to a great extent like quality control, it also is different in many respects.

I don't believe it is necessary to dwell on the similarities. We are familiar with the tools and techniques of statistical quality control and realize that reliability is a fertile field for the application of all of these techniques. Also, it has already been emphasized that the achievement of reliability necessitates a strong and effective Quality Control Department. At Bendix our Quality Control Department is responsible for vendor quality liaison, inspection, test, test equipment design and maintenance, environmental testing, and reliability. We feel it is strong and effective.

Let's look now at differences between reliability and quality control.

1. Reliability Deals More Closely with Engineering

From the material in the previous section you can see that reliability and engineering have a tendency to overlap in function. Your past experience has shown you that quality control and manufacturing have this same tendency. Consequently, just as some quality control departments are organized under manufacturing, some reliability groups are organized under engineering. You will say "Quality Control deals with Engineering, too." I would agree with this, but isn't it true that when quality control deals with engineering the purpose is to get specifications relaxed? When reliability deals with engineering, the purpose is to get specifications tightened.

It seems to me that the growth of reliability in the last three years has been largely occasioned by a realization on the part of design engineers that they could use the subject of statistics to help them in their work. They have had a sufficient technical background to grasp the underlying mathematical concepts of statistics and assimilate this subject matter with their previous knowledge. This has resulted in a wealth of papers on engineering applications of statistics. On the other hand, I don't feel that the statistician or the quality control engineer has kept pace technically with the increase in complexity of electronics. Definitely, in the words of Dr. Mason Wescott, "The cook book 'ain't' enough" in electronics.

I realize that the engineer and the statistician have a language barrier. However, each can offer the other something if they will just try. To quote Dr. Albert Whitehead, philosopher and mathematician:

> *"When you get a group of diverse professional people in a discussion, their experience is so varied that you are sure to get novel contributions to the idea. None of them may be final, some of them may not be valid, but all of them will make some contribution to the subject, and while perhaps they cannot be accepted, they will bear study."*

Let me bring up at this point the antipathy that appears to exist between the statistician or quality control engineer and the engineer. It seems to me that some statisticians assume there is no physical law underlying their data and believe only what the data say regardless of their physical plausibility, while some engineers take no cognizance of variability but believe all results will follow the applicable formula. It has been pointed out to me that engineers realize that although all things will follow their formulas, the variations of materials and testing instruments will introduce variation from the nominal. It seems to me that as a group, statisticians working in electronics must learn more of the fundamentals of electronics and more about the products with which they are working. In electronics where the sample sizes are often minute, it is necessary to rely heavily on engineering judgment in evaluating test results.

2. Reliability Is More Interested in Equipment Life

Going back to the original definition of reliability,

> "Reliability is the probability that a device, equipment, or system will perform its intended function for a specified time under given conditions."

we see the phrase *"for a specified time."*

Time is a quality characteristic with which most QC engineers are not vitally interested. To a great extent the QC engineer deals with what we call "zero time" quality. For instance, parts are sampled following MIL-STD-105A and given "zero time" test in Receiving Inspection. They are then assembled and given a "zero time" test on the line. True, in electronics work most parts have to pass an extended time qualification test, and on occasion, a complete assembly is given a "life test," but the emphasis is on keeping the number of defects down in the manufacturing process and the assumption is made that if the unit passes the test at the end of the line it will hold up in use.

In reliability, the emphasis is different. Usually the cost of the unit is so high, particularly in prototype equipment, and its mission is so vital, that the *number* of defects occurring in the factory is really not the important factor. It is assumed that *every* unit will leave the factory perfect. The question is "How long will it stay that way?"

For this reason, the percent defective of a lot of material coming in to a missile manufacturer's Receiving Inspection Department is almost immaterial. A much more important question is: Of the material received which is now good, what is its "mean time to failure?" This means that

much more than the normal extended time-testing of received components is necessary to insure that the quality presented by the vendor in the first batch of material he submitted is being maintained.

3. Reliability Emphasizes Immediate Corrective Action

Quality control has emphasized controlling the process. This means assuring that the defect practically never occurs again once it has occurred the first time. Quality control de-emphasizes the remedial activity on the defective material once it has been found.

Reliability working in an expanding program cannot afford to slight such remedial action. If a process is wrong, it is true it must be corrected, but it is equally important to rectify the damage that has been done to the defective material. If the material on hand is flown in a hazardous condition today, we may not have a process or a program tomorrow. As a program matures the emphasis can be shifted from immediate corrective action on defective material to process control. In a new program it is one of reliability's main tasks to see that known hazards in hardware are eliminated.

4. Reliability Is More Interested In The Nature of the Defect Than The Defect As a *Statistic*.

In the early stages of a missile program, the reliability engineer is more interested in the nature of discrepancies than he is in the number of discrepancies. At this stage the control chart for percent defective will not do the job for him. In the first place, everybody knows the process is not in control. Scores of changes are occurring every day. In the second place, it is not how many discrepancies occurred, but what were they.

If a tester on the line sees a new defect, for instance a loose tube-socket pin that he has never seen before, this one event can have great significance, and yet never show up as an out-of-control point on a chart. The reason for its significance is that it indicates the physical possibility that such events can happen again and perhaps have happened before. There is therefore indication of a change in the physical parameters inherent in the process—a design has been changed, a process has been changed, or a new batch of material is defective. It is not this event as a number or as a statistic that is important, but the nature of the event in terms of its past history which is important. To a tester working closely with a piece of equipment, single instances of this type stand out like a sore thumb—if a reliability attitude has been sold.

5. Reliability Is Interested In Improving the Status Quo—Quality Control Is Interested In Maintaining It

In quality control the main job is to keep a process in control, meeting the standards which are agreed to be satisfactory. The "Quality" of an item is thus accepted as a management decision, as Ford quality, Cadillac quality, and it is the job of quality control to see that management's standards are put into effect.

In reliability the emphasis is placed on upgrading all standards. As equipment gets more and more complex, standards must become more and more severe. Unfortunately the standards for piece parts or components do not keep pace with the reliability requirements for systems of increasing complexity.

As an example of this, the reliability specifications which are being written today include the ingredient of time, but the military specs of the parts to be used in the manufacture of such products do not emphasize sufficiently the importance of long life under valid conditions. I do not wish to go into the mathematics of this situation. Suffice to say that the complex missiles being made today require electronic parts which have a mean life to failure of 50,000 to 100,000 hours, if the probability of missile success is to be as high as 90 percent for periods of approximately ten minutes. (Assuming that the distribution of electronic part failures follows the exponential failure law).

What does this mean to the missile manufacturer? It means that there aren't piece part specifications good enough for missile use and he must add on his own requirements to MIL Specs. This results in so called MIL-plus Specs. What does this mean to the component manufacturer? It means that he is asked to supply a part that is definitely above what is a normal industry standard by a portion of his market of almost negligible size. What does this mean to the taxpayer? It means that scores of missile manufacturers are running qualification tests on the same parts without an interchange of data, and the duplication of effort is huge.

Conclusion

The purpose of this article has been to acquaint you with reliability and to point out the similarities and differences of reliability and quality control. It has also been to show you something of what the repercussions of reliability will be on all manufacturing concerns in the years to come.

To summarize what reliability is and how it is like and different from quality control, I submit the following definitions of a reliability engineer written by Mr. Robert Bolles, Office of the Assistant Secretary of Defense, Applications Engineering.

> "This bird we have called a reliability engineer has a long bill with two special functions; poking into other peoples' business and puncturing the more highly inflated egos of those design engineers whose beautiful black boxes are quite inappropriate to the military scene. On the one hand, this bird is a relentless hunter of gremlins, fairies, jinxes, and bugaboos, while on the other he is a kind of altruistic cuckoo, throwing out of the contractor or military nest the comparatively useless eggs of the domesticated and cagebound designer and laboriously carrying to the next the words of wisdom laid by his own close kin, his fellow reliability engineers."
>
> "In plainer language, the reliability engineer is a researcher, of high scientific competence, who has learned that a device of great technical elegance, capable of remarkable performance in the hands of a picked crew, is not necessarily a good weapon of war. He is the instrument for building into the design, provisions which depend on close analysis of the vehicle environment in which the device is to operate, the field conditions, and above all things, the competence of those who are to operate, maintain, and repair it."

So far reliability activity has been restricted to relatively large companies working on complex weapons systems. In the future, as reliability specifications are more clearly imposed on weapons systems contractors, it is more than likely that reliability specifications will then be written on all of the many components which go into such systems. When this time comes many of you will then become actively engaged in this business of Reliability. I think you will find it interesting and challenging and that you will be able to make significant contributions by virtue of your quality control experiences and training.

Sampling of Paper and Paper Products

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Preface

This method was prepared in 1950 and has been a Container Corporation standard (CCA - T(C)ml) since 1952.

It is based on certain principles characteristic of tests run on paper and paper products:

1. Paper and paper products can be specified in terms of attributes, variables, or both.
2. Variables sampling applies to testing paper and paper products because paper tests are generally normally distributed. We have not, in fact, ever encountered any variables which followed any other kind than a normal distribution.
3. Lot screening, except for some attributes on products divisible into units is almost impossible. This is true because most measurements are either destructive in themselves, or the removal or preparation of the test specimen necessitates the destruction of an item of product.

We wish to acknowledge our gratitude to Mr. L. J. Jacobson of the International Resistance Company of Philadelphia for permitting us to use his nomograph in our standard.

1. Scope

a. This method describes the procedures for sampling paper and paper products and provides criteria for making consistent decisions based on the evidence from the samples as to whether a lot of material does or does not conform to specifications.

b. Paper and paper products may be classified as bond, writing, printing, envelope, wrapping, building, glassine, and condenser paper, paperboard, and container board in rolls, skids, frames, cases, or bundles, solid fibre and corrugated containers; folding and set-up cartons; fibre cans; bags; paper towels and tissues.

c. Two procedures are recognized in this method, as follows:

Commercial Sampling Procedure
Referee Sampling Procedure

These two procedures are to be applied to both qualitative and quantitative specifications.

2. Definition of Terms

a. The term *"lot"* shall mean "inspection lot," i.e., a collection of units of product about which it is desired to make a judgment as to conformance to specifications by examining or testing a small fraction, called the sample.

b. *Unit of Product* is the entity of product inspected. It may be a discrete piece such as a sheet, a container, a carton, a bag, etc. It may be a single article, a pair, a set, a length, an area, etc., of the finished product or a component thereof. The unit of product may have to be arbitrarily chosen in those cases where material presents no natural division into discrete pieces, for example in the case of roll stock.

c. A *sample* is one or more units of product drawn from a lot, the units of the sample being selected without regard to their quality.

d. *Qualitative or attribute specifications* are defined as those of a non-numerical nature, that is, classification of the characteristic of the unit of product into one of two classes. Example: the unit of product has correct or incorrect dimensions, contains or does not contain a flaw, is defective or non-defective, etc.

e. *Quantitative or variables specifications* are defined as those of a numerical nature, that is, measurement of a characteristic on a continuous scale. Example: tensile strength, weight, brightness, moisture content, etc.

f. A *defective* is a test unit showing any deviation from the requirements of a specification, design, contract, or order. For qualitative specifications, it is a test unit falling outside the tolerances, containing a flaw, or failing some other visual attribute. For a quantitative specification it is a test unit whose numerical test value is less than a specified minimum or more than a specified maximum limit or both. The *fraction defective* in the sample is the number of defective test units divided by the total number of units tested.

g. *A desirably low value of fraction defective* is defined as the average fraction defective that can be tolerated by a consumer while still retaining satisfactory, economic functioning of the material.

h. An *undesirably high value of fraction* defective is defined as the fraction defective that prohibits satisfactory, economic performance of the function of the material.

i. *The producer's risk* is defined as the probability or the chance the producer takes that, on the basis of the sample evidence, a lot of material actually having a desirably low fraction defective will be judged as not conforming with the specification.

j. *The consumer's risk* is defined as the probability or chance the consumer takes that the judgement will be made that a lot conforms to the specification when the true fraction defective is actually undesirably high.

3. Report

The report of commercial and referee testing results shall include the information shown in Fig. 1.

4. Description of the Lot

a. A lot should consist of product available in its entirety for sampling at one time. So far as possible it should consist of material that has been produced under what are judged to be the same essential conditions. An attempt should be made to avoid grouping together batches of product that are likely to differ from one another because of differences in raw material or manufacturing methods or conditions. The lot size should be as large as possible consistent with these and other economic and technical considerations. Small variations from the usual lot size are permissible. It must be clearly reported what quantity of goods constitute a lot.

b. The lot must be such that it can be sampled by practical systems. A roll from which sample units can be taken at only one spot cannot be considered a lot unless special provision is made to obtain sample units at random *throughout* the entire roll.

c. A complete description of the lot to be sampled and tested to determine conformance to specifications should be agreed upon by the parties involved. This description should include the quantity, size, weight, etc., of the rolls, skids, bundles, etc., submitted.

Sampling for these tests has been carried out according to CCA Standard T(C)ml

Specification: _____

Decision: Lot conforms _____

Lot does not conform _____

Description of lot: _____

Usual number of items: _____

Maximum _____ Minimum _____

Designation of sample unit: _____

Randomizing procedure used: _____

_____

Desirably low value of fraction defective (p_1) _____

Undesirably high value of fraction defective (p_2) _____

Producer's risk (α) _____

Consumer's risk (β) _____

Sample size (n) _____
(number of sample units)

Acceptance number (c) _____

No. of defective _____

Coefficient of variables conformance criteria (k) _____

Sample average ($\bar{X}$) _____

Standard Deviation (s) _____

Figure 1

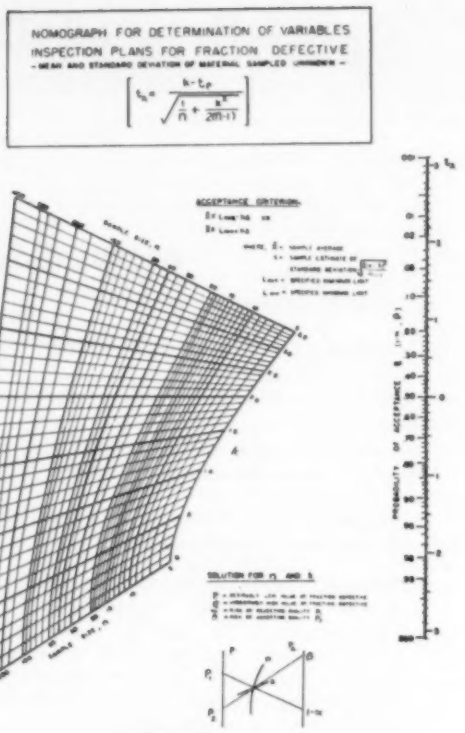


Figure 2

5. Method of Selecting the Sample Units

a. The inspector should attempt to draw items from a lot so that these items constitute a sample that fairly represents the quality of that lot. The type of sample most nearly meeting this condition is a "random" sample. Effective randomization cannot be accomplished by the simple expedient of issuing instructions to "choose units at random" or take a "representative sample." The randomization must be deliberate, objective, and planned. Neither familiarity with the process or the product can be substituted.

b. This randomization can be achieved only by some procedure which is *equivalent to*:

1. Assigning numbers to the sample units or items in the lot.
2. Drawing numbers from a hat of chips or tags or a table of random numbers to decide which sample units are to be in the sample (see "Table of Random Numbers" on page 22).

There are many modifications of this method which give every unit in the lot an equal chance to be included in the sample and eliminate the possibility that the quality of the unit has a bearing on whether or not it is included in the sample. Among these, are the use of decks of cards, wheels of chance, dice throwing, etc. A short table of random numbers is included in this standard for use in selecting sample units or items. An illustration of its use is given in Note 1.

c. In the case of rolls, care shall be taken to select units that are not damaged. It is good practice to discard the first three layers of the roll to be sure of obtaining a sample unit in good condition.

d. The sample units of sheet paper or board shall be trimmed with their edges exactly parallel to the machine and cross direction.

e. The units in the sample should be handled throughout in accordance with all the usual precautions of the best laboratory techniques and of the standard test methods applying. The sample units shall be kept smooth and flat, and protected from exposure to direct sunlight, contact with liquids, moisture of the hands, and other harmful influences. Units to be tested for moisture shall be placed immediately in an airtight container for storage. Physical tests shall not be made on test units in which there are flaws or watermarks.

f. Samples collected without use of objective randomization procedures should not be used for determining conformance to specifications unless producer and consumer so agree. The report should note such an agreement.

6. Determination of Sample Size

a. The number of units which make up the sample depends chiefly on technical and economic considerations of the quality and the degree of protection required. The quantities defined in Sections 2 (g, h, i, j) i.e., the desirably low value of fraction defective (p_1), the undesirably high value of fraction defective (p_2), the producer's risk (α), and the consumer's risk (β), form the basis for determination of sample sizes for both the qualitative and quantitative specification tests. The decision as to what are reasonable for these, and the specification of what constitutes the maximum and minimum limits above and/or below which the unit shall be considered to be defective, is a matter which must be left to the judgement, skill, and knowledge of the producer and consumer, between whom a mutually satisfactory agreement shall be reached.

b. In the case of referee tests the producer's risk shall be 0.05, 5 percent and the consumer's risk shall be 0.10, 10 percent.

c. Two charts are included in this standard which make it possible to determine a sample size given the four quantities listed in (a) above. The first of these (see Fig. 2) is for use where quantitative measurements are made. An example of its use is given in Note 2 (a). When only qualitative classification is used the second chart (see Fig. 3) is to be used. An example of its use is given in Note 3 (a).

7. Decision as to Conformance

a. The conformance criteria for the variables sampling plan is based on the average $(\bar{X})^*$ and standard deviation $(s)^*$ of the sample test values. The lot is judged to be conforming if for the sample

$$\bar{X} \leq L_{max} - ks \text{ (for a specified maximum limit)}$$

$$\bar{X} \geq L_{min} + ks \text{ (for a specified minimum limit)}$$

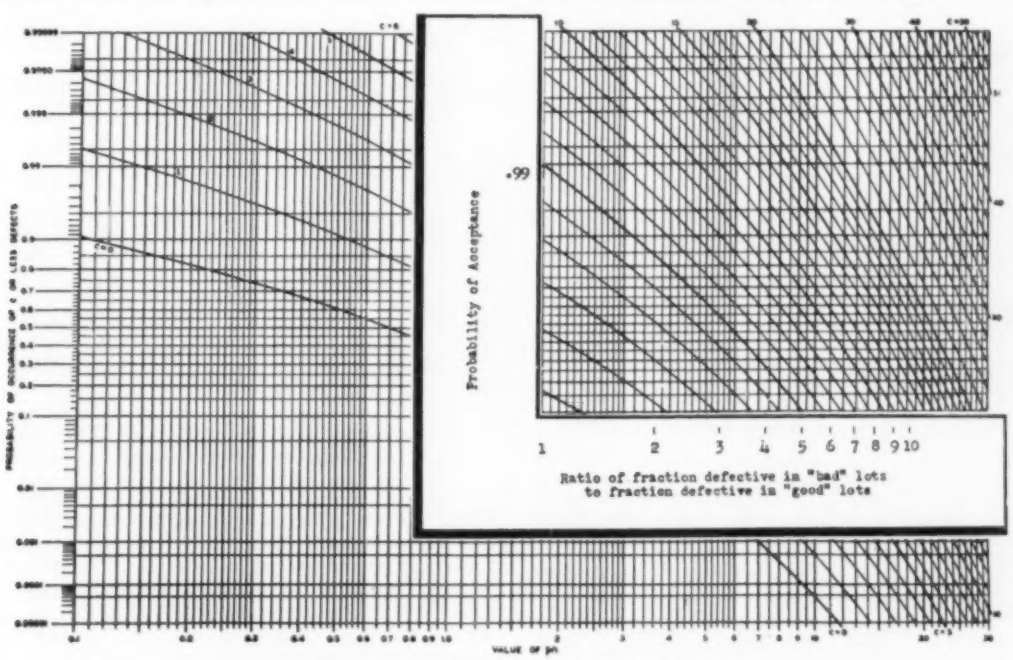
otherwise it is judged non-conforming. A sample calculation is given in Note 2 (b).

b. The conformance criteria for the qualitative sampling plan is based on the number of defectives found in the sample. The lot is judged to be conforming if for the sample the number of defectives is equal to or less than the acceptance number c. If the number of defectives is greater than c the lot is judged non-conforming. An example is given in Note 3 (b).

$$^*\bar{X} = (X_1 + X_2 + X_3 + \ldots\ldots + X_n)/n$$

$$s = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2/n}{n-1}}$$

where X is an individual test value obtained from a test unit; n is the total number of test units in the sample.



GRAPHICAL SOLUTION OF DETERMINATION OF SINGLE SAMPLING PLAN

Example Shows Plan Which Will Accept 2% Defective Material 99% of the Time, but Accepts 10% Defective only 10% of the time.

(Chart reproduced by permission from "Sampling Inspection Tables," H. F. Dodge and H. G. Romig, John Wiley & Sons, New York City)

Figure 3

8. Examples and Comments

Note 1

Let the lot consist of 100 bundles of 10 units per bundle. A single sample of 24 is required. Number the bundles from 1 to 100. Draw 24 numbers from the random table between 1 and 100. The table can be entered at any point and consecutive numbers taken by going down a column, across a row, or diagonally across a page, discarding any number that turns up a second time. For this example the numbers were taken starting in the extreme left hand column and going down the columns in turn from left to right. These numbers indicate which bundles are to be set aside for sampling. Then choose a number from 1 to 10 to be associated with the 24 previous numbers. This second number indicates which unit in the bundle is to be selected. On the first drawing the numbers in the first column (before the dash), and on the second drawing the numbers after the dash were obtained as shown below:

16—1	78—3	91—2
18—1	3—7	50—5
73—7	74—10	65—4
57—5	9—7	27—9
30—3	42—10	37—9
96—1	21—4	11—5
38—9	55—1	46—6
31—3	44—2	30—2

A double number such as 8—3 designates the 3rd unit in the 8th bundle. The units corresponding to these numbers are selected as designated, forming a sample of 24 sample units from which 24 test units are obtained, one from each sample unit.

Note 2

a. Let it be required to determine a sample size for testing conformance of the mullen strength of a lot where the specified minimum limit (L_{min}) is 200 lbs., the desirably low value of fraction defective (p_1) is to be 0.05, the undesirably high value of fraction defective (p_2) is to be 0.20, with the producer's risk (α) at 0.05 and consumer's risk (β) at 0.10.

On the nomograph, draw a straight line connecting the fraction defective, $p_1 = 0.05$, on the left hand vertical scale and the associated probability of acceptance, $(1 - \alpha) = 0.95$, on the right hand vertical.

Then draw a straight line connecting the fraction defective, $p_2 = 0.20$, on the left hand scale and the associated probability of acceptance $\beta = 0.10$, on the right hand scale.

These two lines intersect on the grid between the two vertical scales at a point defined by $n = 24$ and $k = 1.2$, which determines a sampling plan. In words, this plan says that the producer shipping a lot of board in which not more than 5 percent of all test units are below 200 lbs. mullen does not run a risk of more than 5 percent that his product will be judged non-conforming by tests on a random sample of 24 units, and the consumer who receives a lot in which 20 percent of the units are below 200 lbs. mullen does not run a risk of more than 10 percent of judging the lot conforming on the evidence of a random sample of 24 units.

b. It will be assumed that the sample units drawn as illustrated in Note 1 (a) according to the sampling

TABLE OF RANDOM NUMBERS

(FROM "ICC" TABLES OF 105000 RANDOM DECIMAL DIGITS)

Line \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
51	16408	81899	04153	53381	79401	21438	83035	92350	36693	31238	59649	91754	72772	02338
52	18629	81953	05520	91962	04739	13092	97662	24822	94730	04492	38999	04838	88774	98289
53	73115	35101	47498	87637	99016	71060	88824	71013	18735	20286	23153	72924	35165	43040
54	57491	16703	23167	49323	45021	33132	12544	41035	80780	45393	44812	12515	98931	91202
55	30405	83946	23792	14422	15059	45799	22716	19792	09983	74353	68668	30429	70735	25499
56	16631	35006	85900	98275	32388	52390	16815	69298	82732	38480	73817	32523	41961	44437
57	96773	20206	42559	78985	05300	22164	84369	64224	35083	19687	11052	91491	60383	19746
58	38935	64202	14349	82674	66523	44133	00697	35552	35970	19124	63318	29686	03387	59846
59	31624	76384	17403	53363	44167	64486	64758	75366	76554	31601	12614	33072	60332	92325
60	78919	19474	23632	27889	47914	02584	37680	20801	72152	39339	34806	08930	85001	87820
61	03931	33309	57047	74211	63445	17361	62825	39908	05607	91284	68833	25570	38818	46920
62	74426	33278	43978	10119	89917	15665	52872	73823	73144	88668	89970	74492	51805	99378
63	09066	00903	20795	95452	92648	45454	09553	88815	16553	51125	79375	97596	16296	66092
64	42238	12426	07025	14867	20979	04508	64535	31355	86064	29472	47689	05974	52468	16834
65	16553	08002	26504	41744	81959	65642	74240	56302	00033	67107	77510	70645	28725	34191
66	81457	40742	29820	96703	29400	81949	15035	34537	33310	06116	95240	15957	16572	06004
67	81581	57802	02050	89728	17937	37621	47075	42080	97403	48686	68995	43805	33386	21597
68	55612	78095	83197	33732	05810	24813	86902	60397	16489	03264	88525	42786	05269	98532
69	44657	66999	99324	51281	84463	60563	79312	93454	68876	25471	93911	25650	12682	73572
70	91340	84979	46949	81973	37949	61023	43997	15263	80644	43942	89203	71795	99533	50501
71	91227	21199	31935	27022	84067	05462	35216	14486	29891	68607	41867	14951	91496	85065
72	50001	38140	66321	19924	72163	09538	12151	06878	91903	18749	34405	56087	82790	70925
73	65390	05224	72958	28609	81406	39147	25549	48542	42627	45233	57202	94617	23772	07896
74	27504	96131	83944	41575	10573	08619	64482	73923	36152	05184	94142	25299	84387	34925
75	37169	94851	39117	89632	00959	16487	65536	49071	39782	17095	02330	74301	00275	48280
76	11508	70225	51111	38351	19444	66499	71945	05422	13442	78675	84081	66938	93654	59894
77	37449	30362	06694	54690	04052	53115	62757	95348	78662	11163	81651	50245	34971	52924
78	46515	70331	85922	38329	57015	15765	97161	17869	45349	61796	66345	81073	49106	79860
79	30986	81223	42416	58353	21532	30502	32305	86482	05174	07901	54339	58861	74818	46942
80	63798	64995	46583	09765	44160	78128	83991	42865	92520	83531	80377	35909	81250	54238
81	82486	84846	99254	67632	43218	50076	21361	64816	51202	88124	41870	52689	51275	83556
82	21885	32906	92431	09060	64297	51674	64126	62570	26123	05155	59194	52799	28225	85762
83	60336	98782	07408	53458	13564	59089	26445	29789	85205	41001	12535	12133	14423	83541
84	43937	46891	24010	25560	86355	33941	25786	54990	71899	15475	95434	98227	21824	19585
85	97656	63175	89303	16275	07100	92063	21942	18611	47348	20203	18534	03862	78095	50136
86	03299	01221	05418	38982	55758	92237	26759	86367	21216	98442	08303	56613	91511	75928
87	79626	06486	03574	17668	07785	76020	79924	25651	83325	88428	85076	72811	22717	50585
88	85636	68335	47539	03129	65651	11977	02510	26113	99447	68645	34327	15152	55230	93448
89	18039	14367	61337	06177	12143	46609	32989	74014	64708	00533	35398	58408	13261	47908
90	08362	15656	60627	36478	65648	16764	53412	09013	07832	41574	17639	82163	60859	75567
91	79556	29068	04142	16268	15387	12856	66227	38356	22478	73373	88732	09443	82558	05250
92	92608	82674	27072	32534	17075	27698	98204	63863	11951	34648	88022	56148	34925	57031
93	23982	25835	40055	67006	12293	02753	14827	23235	35071	99704	37543	11601	35503	85171
94	09915	96306	05908	97901	28395	14186	00821	80703	70426	75647	76310	88717	37890	40129
95	59037	33300	26695	62247	69927	76123	50842	43834	86654	70959	79725	93872	28117	19233
96	42488	78077	69882	61657	34136	79180	97526	43092	04098	73571	80799	76536	71255	64239
97	46764	86273	63003	93017	31204	36692	40202	35275	57306	55543	53203	18098	47625	88684
98	03237	45430	55417	63282	90816	17349	88298	90183	36600	78406	06216	95787	42579	90730
99	86591	81482	52667	61582	14972	90053	89534	76036	49199	43716	97548	04379	46370	28672
100	38534	01715	94964	87288	65680	43772	39560	12918	86537	62738	19636	51132	25739	56947

plan picked out in Note 2 (a) produced test results as listed below:

216	218	219	220
217	223	222	224
221	219	218	216
219	222	220	222
218	224	219	223
219	217	223	220

These values are summed and divided by 24 to give the average, $\bar{X} = 220$. Each value is squared and the sum of these squares is substituted in the formula for the standard deviation,

$$s = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2/n}{n - 1}}$$

For the above values, $s = 2.46$. This average and standard deviation with the minimum limit and k given in part (a) above are substituted in the conformance criteria for specified minimum limit:

$$220 \geq 200 + (1.2)\ (2.46) = 203$$

Since the average is higher than the quantity on the right hand side of the equation, the lot is judged as conforming to the specification.

Note 3

a. This method of determining a sampling plan is based on the fact that the pn scale on the chart (see Fig. 3) is logarithmic, so that the linear distance from 1 to 2 is the same as from 2 to 4, or from 4 to 8, and so on. Cut an L-shaped piece of plastic, and along the horizontal edge of this L plot the pn ratio, which is the same wherever we place this scale on the chart. No scale is drawn along the vertical axis of the L.

Let it be required to devise a sampling plan which will judge 2 percent defective ($p_1 = 0.02$) material conforming 99 times out of 100 (producers risk, $\alpha = 0.01$), but will judge as non-conforming at least 90 times out of 100 (consumer's risk, $\beta = 0.10$) material that is 10 percent defective ($p_2 = 0.10$). First, determine the "operating ratio", i.e., the ratio of the undesirably high value of fraction defective (bad lots) to the desirably low value of fraction defective (good lots):

$$p_2/p_1 = 0.10/0.02 = 5$$

Then set the L on the chart, with the horizontal scale edge coinciding with the consumer's risk line, which is 0.10 in this example. Make a pencil mark on the vertical edge which coincides with the required producer's risk which in this case is $(1 - \alpha) = 0.99$. Now slide the L horizontally until a position is found such that some c curve passes through the point on the vertical scale, and also through or just to the right of the proper operating ratio number on the horizontal scale. For the example shown, this requirement is met by the $c = 5$ line. Since the corresponding value on the pn scale is 1.8, the sample size is given by:

$$n = pn/p_1 = 1.8/0.02 = 90$$

b. It will be assumed that a sample of 90 units was drawn from a lot by the methods given in Note 1 according to the plan found in (a) above. These units were to be classified as "dirty" or "clean" by visual comparison with a set of standards. By definition, those classified as "dirty" will be the defectives. Ten such defectives were found in the samples of 90, and the lot is therefore judged to be non-conforming, since the acceptance number c is equal to 5.

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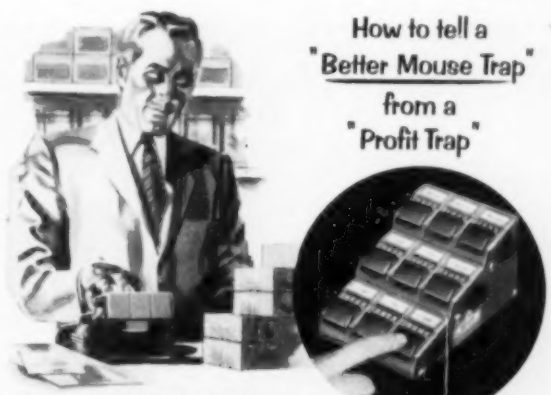

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a key to higher quality on low quantity production

WILLIAM R. BAKER

Parker Aircraft Co., Subsidiary of Parker-Hannifin Corp., Los Angeles, Calif.

Standard inspection procedures based on statistical samplings of machined parts do not control quality; they only report quality. This is satisfactory if only a few machining operations are involved between inspection stations, but it can be expensive and wasteful whenever a number of operations are performed by a single machine operator. A large amount of machine time may be devoted to a part that is already off-specification, and a number of rejects may be produced before routine inspection catches the error.

Obviously, an inspector cannot be assigned to each work station. This would be uneconomical, too. The answer, as developed by Parker Aircraft Co., is to make each machine operator a part-time inspector. The "egg-crate" inspection system, as it is called, assigns the operator the task of running a continuous check on his own work. It takes a certain proportion of his time, but the results are worth it. In one case, Parker switched to the egg-crate system and immediately dropped its customer rejection rate on a complex hydraulic control mechanism from 10.9 percent to 0.70 percent.

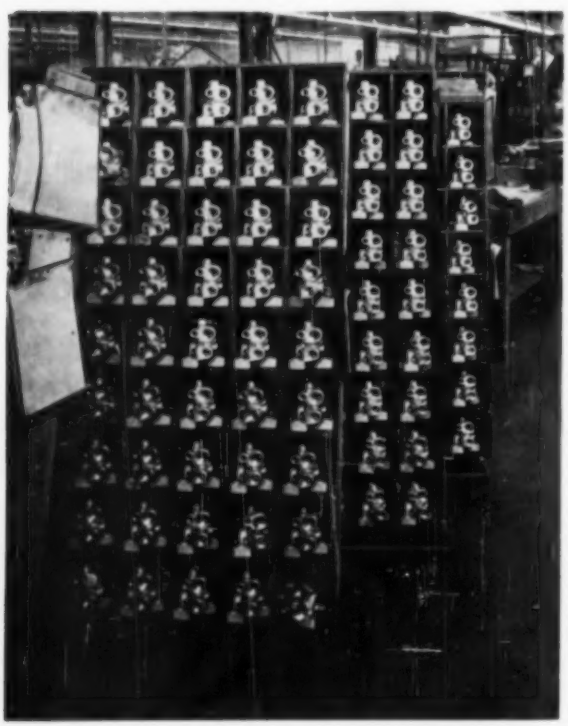

Figure 1—Hydraulic valve bodies in egg crates are awaiting machining. Parts are arranged in the crate in numerical order. Latest engineering drawings, gaging lists, and routing slips are attached to the side of each egg crate.

The egg-crate system gets its name from the rack that is used to contain all parts during machining operations. This rack (see Fig. 1) closely resembles an egg crate. When a group of parts are ready for machining, they are delivered to the machinist in the crate. After each part is machined, it is returned to its own egg cell. Each part remains in its cell throughout the entire manufacturing process. (Figure 2 shows a machinist and his "egg-crate" and Figure 3 shows a production line set-up.)

What is the Egg-Crate System?

Egg-crate quality control combines progressive sampling by the machine operator with random sampling by inspectors.

Progressive sampling by the operators, and the manner in which the sampling is done, are unique features of the system. The frequency of check is determined, as in any inspection system, by the Director of Quality Control. He determines the maximum number of parts in a group that can be allowed to escape rejection. Using statistical tables, he can then determine how many parts out of every hundred or every thousand must be inspected. For example, every fifth part is inspected at Parker when a certain type of valve body is being machined.

In this particular case, rough bodies arrive at Parker after they have been cast. They are first inspected for defects as required by Military Specifications. Prints and routing orders are checked for possible revisions. This insures that the bodies will be machined according to the latest specifications. Chemical and physical analyses of the parts are reviewed to be sure that they meet specifications. (When the bodies were cast a job number was stamped on each part; in this way, the chemical and physical properties of each casting can be determined during production and after delivery). If the bodies pass this inspection, they are ready for machining.

Each part is next placed in an egg-crate. As each part is put in its cell, it is stamped with a number. If there are, for example, 100 castings in a group, the first casting placed in the rack is stamped number one, and the rest in numerical order. These numbers are also put on the purchase order for future reference. The latest engineering, routing, and process drawings are

attached to each rack. Then the rack is released to production.

Machining of each body is done in numerical order. The machinist starts with part one and works in order to part 100, or to whatever number of parts there is in a single rack. A gaging list is included in the process drawings attached to each egg-crate.

Gaging List

The main purpose of the gaging list is to provide the Inspection Department with an accurate progress and condition report. An example of a gaging list is shown in Fig. 4. The list shows the machinist the dimensions that must be checked and the frequency of check that must be used in order to maintain a high standard of quality.

Figures in the top row of the gaging list are part numbers. All entries in the left column show the dimension which must be checked. When a valve body meets all requirements, operator's initials are entered in the proper square. (Clock number is not used as it is related to regimentation). If the part does not meet the requirements, then a check must be put in the square. When finding a part that does not meet specification, the machinist checks all parts since the last inspection.

For example, suppose that the body numbered 15 passed, but the body numbered 20 did not pass inspection. Then the four preceding parts (19 through 16) are checked to see if they pass inspection. In this way the machinist can readily determine if he has made an error on one part, or if his tooling needs adjustment or replacing. Instead of having to check through a whole group of parts, only four must be checked. Furthermore, if something has happened to the tooling, a very small number of parts have been worked before the trouble is found.

Rejected Parts Remain in Rack

When a part fails to pass inspection, it is reworked as soon as possible. If rework is impossible, MRB action is taken; if scrap, the part is painted red and replaced in the rack. (Spray can is in possession of inspector). This is an important feature of the egg-crate system. Then the actual condition of the part, along with the part number, is recorded on the back of the gaging list.

Leaving rejected parts in the egg-crate serves several functions. First, it gives the machinist an indication of the quality of his work. Naturally, a good man does not want his rack filled with rejected parts. Second, it permits the foreman to isolate the cause of a high rejection rate. He can immediately determine which operator and which machine are responsible. This allows adjustments to be made, if necessary. Third, it allows the production planner to estimate how many acceptable parts he will have at the end of machining. Fourth, it simplifies the work of Quality Control in determining the reject percentage. Fifth, assignable causes are quickly determined by action committee of Quality Control, Production, Process Engineering and, if necessary, Design Engineering.

Random Inspection

During machining, inspectors check parts along the line. Parts, other than those checked by the machinist, are spot checked. The inspector is also responsible for seeing that the proper gaging lists are at each operation. Furthermore, he is responsible for maintaining detailed corrective action reports on the back of the gaging lists, including tool changes, fixture correction, and operator instruction.

When machining operations are completed, a review of the gaging lists and rejects is made. Scrap parts are removed from the egg-crate, and visual inspection is performed on the remaining parts to see if any damage has occurred during handling. If no damage has occurred, the parts are released.

By using the egg-crate system, final inspection has been eliminated; inspection along the line replaces the final inspection. Therefore, fewer inspectors are required and the Inspection Department becomes a true Quality Control Department.

Master Books Maintained

Quality Control maintains a master book on every run that is being made in the plant. The master book

Figure 2—Machinists remove parts from egg crate for machining. Following machining operations, each part is placed back into the cell from which it was removed. Gaging list is placed directly behind machinist so that it can be easily checked. Tag located on cell where part is missing gives reasons why part has been removed and its present location. Other missing part is being machined.

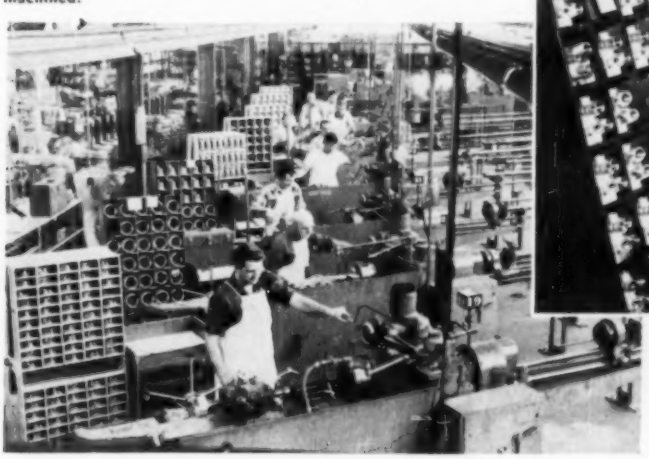

Figure 3—The egg crate system is used extensively in the Hydraulics and Fuel Divisions of Parker Aircraft Co. The crates can be easily modified so that they will hold parts of different sizes and configurations.

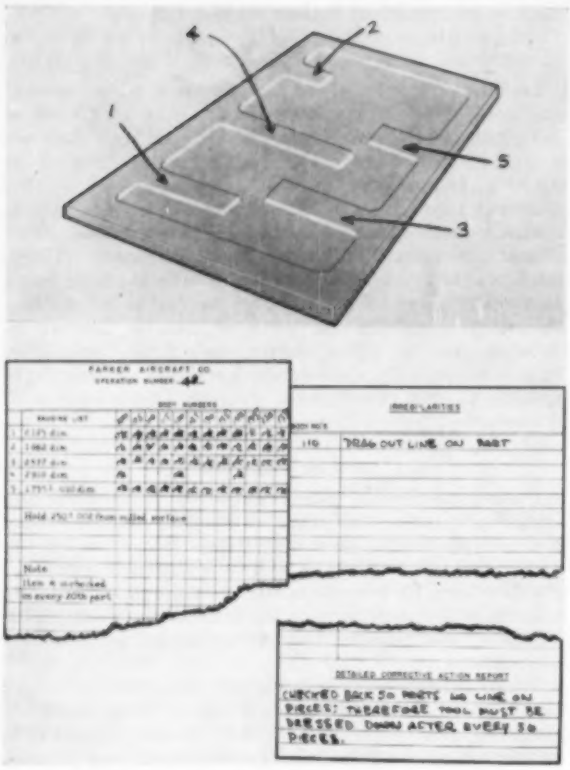

Figure 4—Detailed inspection and corrective action reports are made on the gaging lists. This enables a permanent record to be kept of every part that has been inspected. In addition, the causes for rejection are easily determined.

includes a gaging list, a guide for the machinist's use of the gaging list, duties of the line inspector, instructions for maintaining proper records of corrective action, and instructions for control of rework by the machinist and by the foreman. The master book contains all information necessary for successful operation of the egg-crate system.

The system increases production and quality, and at the same time, reduces scrap and rework. Since the machinist inspects his own work, he becomes more conscious of quality. Therefore, he will produce fewer rejected parts. This cuts down the amount of rework required, and as a result, more time is spent in producing acceptable parts. In some cases, Parker has found that its production has almost doubled. Furthermore, the machinist knows the capability of himself and of his machine.

An important feature of this system, from the viewpoint of quality control, is that the system proves machine capability as production proceeds. In other words, machine capability is proved at the same time parts are being inspected.

Arguments Against the System

The main argument presented against this system is that checking is done on the line by the operators. Since time is spent checking, the operator cannot produce as many pieces. This argument simply is not valid, at least in Parker's experience. In many cases, the total plant productivity goes up, due to a decrease in the number of rejections. Furthermore, the machine seldom stops. Inspection is carried on as the machine is working. Since the system definitely reduces the number of rejects, up to 90% in some cases, the machinist spends more of his time producing acceptable parts. In order to reduce the time required for checking, however, the best inspection tools and the simplest means of checking are provided for the machinist.

Another argument brought forth against the system is that theoretically the system will work, but since the machine operators must carry on two separate categories of activity, how is it possible to obtain union endorsement of such a plan without up-grading and retiming every job?

In answer to this question, one point should be made clear. The system, as has been outlined here, has been employed very successfully for some time in the Engine Accessories Division in Cleveland, as well as in the Fuel and Hydraulic Divisions of Parker Aircraft Co. in Los Angeles. In both instances the unions have endorsed this plan because of the manner in which it was set up and presented to them. The egg-crate system, therefore, has worked as well in practice as in theory.

Up-Grading Not Required

Every well established plant or machine shop has job classifications such as machinists, drill press operators, milling machine operators, inspectors, etc. Embodied in each classification is a complete job description, which describes in detail what the man shall be capable of so far as workmanship and inspection of his own work. Each man is then paid according to his job skill and according to the job classification.

The job descriptions at Parker for each type of operator clearly state "that each operator must be capable of working to extremely fine tolerances." Therefore, in order for an operator to be able to work to very close tolerances, he must be able to check his work with standard checking equipment, such as micrometers, depth micrometers, go-no go, indicator gages, etc. As a result of this classification, each machinist knows that when he is hired he must be able to check his work. It is impossible to produce high precision parts without some checking by the machine operator. As was stated previously, standard inspection procedures based on statistical samplings of machined parts do not control quality; they only report quality. Therefore, to eliminate high scrap and rework rates, large amounts of sorting, and variances at assembly, parts must be inspected as they are machined.

In most cases, machinists or operators are paid a higher rate than the line inspectors who are inspecting the work within the confines of the operators' classifications. It must be pointed out that the operators are not required to do lay-out inspection. They are only required to use standard inspection equipment used by lower paid inspectors.

Generally, a man is expected to do work that is equal to, or less than, his skill calls for. In these cases, there is no valid excuse for the union or the employee to demand higher rates of pay for inspecting his own work.

Therefore, in cases where machinists are producing parts to close tolerances, they are most likely inspecting their own work. As a result, they are required only to continue their inspection at regular predetermined intervals, and to record the results of their findings. Placing the parts in the egg-crate itself obviously does not require any additional work since they must place them in some sort of a cart or box following machining even in cases where the system is not used.

Retiming May Be Required

The Fuel and Hydraulic Divisions of Parker Aircraft Co., where the egg-crate system is used extensively, is not on standard or piece work rates primarily due to short production runs. Therefore, retiming has not been required. However, the Engine Accessories Division in Cleveland operates on standard rates that have been incorporated after standardization and stabilization of frequency checks based on the egg-crate sampling plan. A time allowance is included in these standards, and inspection personnel are responsible for making sure that the checks are made.

In order to put the egg-crate system into effect, standards must be revised. At every operation where an inspection must be made, the time to produce each part must be changed in order to account for the time spent on inspecting. At no time should the operators be required to do any operation that is not allowed in the time standards. Therefore, it is essential that all time standards be reviewed, prior to installation of the system, guaranteeing that adequate time has been allowed for inspection. Although the time per operation is slightly increased, overall time savings are made because of the many advantages of the system that have been previously mentioned.

Close cooperation between the Standards Department and Quality Control is essential to determine the proper standards that are to be used. Quality Control first should check with all production supervisory personnel to determine the minimum amount of inspection to be enforced by production supervision. Then Quality Control determines the frequency of inspection. After the frequency of the inspection cycle has been determined, Standards either accepts or opens it up for discussion prior to the determination of piece work rates or standards.

For example, Quality Control, after consultation with production supervisors, determines that a certain dimension on a valve body has to be checked every 15 parts. Inspection is to be performed by the operator by inserting a standard go-no go gage. The time required for this inspection operation is determined by the Standards Department from a standard data source, and was found to be 0.118 min. Therefore, the inspection time allowed on each part is 0.0079 min. (0.118/15).

Where the System Works Best

A point to keep in mind is that this system works best in a process where the operator is required to do a number of operations. In machining valve bodies, for example, one operator may perform as many as 12 different operations. If the operator performs only one or two operations, an adjustment is made on frequency checks. The advantages of progressive samplings are twofold; first, it is possible to prevent work from being done on rejected parts, and second, in cases where the tooling is faulty, a minimum number of parts are produced before the trouble is detected.

Wherever possible, variable checking equipment is provided at Parker because it can be adjusted to any subsequent runs of like nature. It is essential that the machinist have the proper inspection tools. The method of inspection is very important. The simplest possible accurate means must be provided or developed—if the machinist is to do the proper job in a minimum amount of time.

Education of Management

To begin the egg-crate or any other quality control system in a plant, management must first be sold, because only with the full-hearted cooperation of management, can the plan succeed. Plans should be presented in a clear manner, so that they can be understood without referring to textbooks. If management must make use of reference materials in order to understand the plan, then shop people probably will not be able to understand it without difficulty. Therefore, the first step is to get the approval and backing of management of a clear, concise plan.

The best procedure is to start the plan in a department that is having a great deal of difficulty with quality or productivity. In this way, when progress is made it will be a greater accomplishment. In addition, the departments that are not having a great deal of difficulty will be impressed by the great improvements that are being made. If the plan is started in a group that is operating very well, the other groups may feel that they cannot be as successful. The important point here is that a certain amount of psychology must be included when trying to create enthusiasm for a plan that on the surface appears to be only additional work for the machine operators and supervisors.

Selection of Personnel

Having selected the department in which to try the egg-crate system, the next important step is to select the personnel who will administer it most effectively. A department head who is willing to accept new ideas must be selected, because the Quality Control Group must be able to sell him thoroughly on the benefits to be obtained from this system. Furthermore, personnel who will follow instructions to the limit must be chosen, for if there is an unpredicted slip-up that does not get reported, the whole purpose of the plan has been defeated.

In addition, inspectors must be chosen who are capable of diplomatic actions. In the egg-crate system any mistake can be traced back to the machinist who made it; therefore, the inspector must be able to tell the machinist that his parts are not satisfactory and he is there to help him find out why. There is more personal contact required in this system than in other types of systems. Supervisory and inspection personnel must therefore be selected carefully in order to obtain maximum benefits.

The entire manufacturing process must be reviewed with the foreman and with the inspectors to be sure that all operations are properly gaged. Each person must be thoroughly convinced that the egg-crate system will improve overall operations. At this point, all should be encouraged to offer any suggestions that will make the plan more effective. Again, methods and not the expenditure of money should be stressed. Now the plan is ready to be presented to the machine operators.

Educating the Machinist

Education of the machinists is very similar to what has been done for management and supervisory personnel. Each operator must be thoroughly convinced in his own mind that he is part of an important operation. He must know that he is making a quality product. In addition, he must realize that the system is not being put into operation to find out how many mistakes he makes, but rather to increase the quality of the product he turns out. He must be shown that he will be able to take more pride in his work because he will learn his own capabilities.

Furthermore, it should be emphasized that he will learn the use of new tools as he checks his work, and that this will make him a more valuable man. High mo-

rale based on recognized good workmanship, and a decent day's work done will in most cases outweigh any other incentives that management can offer.

Results

On the surface, the egg-crate system might appear awkward and laborious. Actually, it becomes very simple after it is put into operation. Not only are less inspection personnel required in the egg-crate system, but also a large reduction in a customer rejection occurs. An improvement in overall efficiency of manufacturing is brought about by improved techniques accompanied by reduced costs for each unit produced.

After a plan such as the one outlined here becomes effective in one department, usually after four months on the average, management generates its own enthusiasm to use the same system in all the production departments where it might be adaptable.

the teaching of Statistics and the training of Statisticians for Industrial Employment

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THE shortage of scientific and professional personnel has become a problem of great national concern. This shortage is being viewed by most people in a fourfold manner—the short term vs. the long term and quantity vs. quality. Decisions that are right for the short run may lead one astray when applied to the long run. Everyone concerned with the production of items, or of skills, knows that quality and quantity are not necessarily independent. Educators have known for years that within a given framework of budget, facilities, and methods, an increase in quantity is often accompanied with a decrease in quality even in the short run, and they accept as an undeniable fact that in the long run the quality-quantity relationship is negative. We should not interpret this to mean that it is impossible to increase both the quantity and quality, but it does indicate that it is the framework which should be investigated. An appropriate solution to the problem of increasing both quality and quantity would be recognized by the student of geometry as one which involved the transformation from one iso-line to another iso-line, the statistician would change from one response curve to another response curve, while the industrialist would program an optimum mix of input for a specified quality of output.

When the quality control engineer finds that his production process is in statistical control, if it ever is, and yet his product is too low in quality, he knows that he can accomplish very little improvement by "cracking his whip" over the technicians, but he recognizes that the chance for improvement lies in the hands of the technologists. Industry has learned that quality cannot be inspected into product. Quality must be built into a product, and this can be done economically only if processes have been appropriately designed. It takes fortitude and foresight for industrial management to retool, and it will take an exceptionally high type of leadership in the field of education to "retool" for increased quantity and quality in our educational process. Although we may accept as a fact that a real shortage of certain critical personnel exists, we may not agree as to the cause, and certainly we shall experience different proposals for remedies. It is not my intent to discuss all of the educational problems facing our leaders today, but I do propose to make a few comments and suggestions concerning the manpower shortage in the field of statistics.

Statistics is a Distinct Discipline

I think of statistics as a discipline separate and distinct from mathematics, economics, or any other subject matter field. A man trained in any of our well-established statistical centers experiences a way of thinking which is not inherent in the philosophy of any other field of study. Unfortunately, the title, "statistician," has been appended to many different job descriptions, but to me it is a professional title in the same manner and on the same high plane as the titles of physicist, chemist, and mathematician. In most of our colleges the teacher of physics is a physicist, the teacher of chemistry is a chemist, but too frequently we find that the teachers of courses labeled statistics are not statisticians at all. More than likely they are economists, or psychologists, or mathematicians who are teaching more economics, psychology, or mathematics than statistics. Throughout this article, as I do in my everyday thinking, I shall use the title, statistician, to encompass that group of professional people who have been trained in the philosophy and discipline of statistics. This does not exclude individuals who have been trained in other subject matter fields but who have learned statistics as a tool essential to research in their chosen field of interest. It is a well-

known fact that some of our most outstanding contributors to the field of statistics have been men from other disciplines.

We find specialization in the field of statistics in these modern times. We hear of the mathematical statistician, the applied statistician, and the consulting statistician. Each of these must choose an area in which to concentrate or else be a jack of all trades and master of none. The field of statistics is fast expanding its horizon, and it doesn't take a very long vacation from statistics to be left behind. The mathematical statistician may choose from many fields such as testing hypotheses, estimation, probability and distribution theory, multivariate analysis, or nonparametric statistics. The applied statistician may select such fields as experimental design or sampling design and, when acting as a statistical consultant, may concentrate on special areas such as, biometry, econometrics, psychometry, or industrial statistics.

Shortage of Statisticians is Acute

The shortage of scientific manpower is especially acute in the field of statistics. This is nothing new, for this has been the situation for the last thirty years at least. It didn't take a Sputnik to point out that we are short of statisticians. The increasing interest in basic scientific research will certainly increase the demand for statisticians. Even in the era B.S. (Before Sputnik), the yearly demand by educational institutions alone would not have been met by the entire production of statisticians at the Ph.D. level. Our graduates are not plagued with finding an acceptable job, but rather they worry about which of the many good jobs is best for them.

Certainly the cause of this shortage of statisticians is a multidimensional one. The increasing awareness by industry, government, business, educational institutions, and research organizations of the importance of statistics as a tool which is useful in procurement, production, marketing, and research and development has been instrumental in determining the demand. The mathematical and statistical approach to decision making is becoming commonplace in many of our progressive and successful organizations in business, government, and industry. On the other hand, educational institutions that are providing effective and complete programs for the training of statisticians are too few in number. A wider geographic distribution of such training centers would be helpful in alleviating the present and ever growing shortage. Although in the past few years several institutions have ventured into a modern program in statistics, these are still too few to train and develop the statistical personnel needed today. Most of our training centers in statistics are less than twenty-five years old. North Carolina State organized its center in the early 1940's, which was about the same time that Iowa State graduated its first Ph.D. with a major in statistics.

Every institution with a major program in statistics is faced with a real shortage of teaching, consulting, and research personnel. The situation of a shifting staff is stifling the statistics programs in several of our Southern institutions. Continuity of staff is a must in any graduate program. Stability of staff may be effected by a policy of careful selection of "good" teachers and well-trained statisticians who are dedicated to the teaching and training of statisticians. Although the pay scale in many institutions is not as high as it should be, a liberal policy of off-campus consulting will assist in warding off the temptations of higher pay which are continuously before each of us.

Although this terrific demand for the very limited supply of trained statisticians poses a very critical problem for the development of a sound and expanding statistics program in our educational institutions, there are other reasons limiting the number of institutions that are willing to embark on a strong program in statistics, or that are willing to strengthen their existing programs. It appears that one of the basic reasons is the failure of our educational and administrative leaders to recognize statistics as a separate discipline, but rather persist in regarding it a branch of mathematics, economics, biology, or some other subject matter field. Too many people feel that statistics for economists should be taught by an economist, statistics for biologists by a biologist, and industrial statistics by an engineer. This is one of the most deterring factors in the development of modern statistics programs. It should be said, of course, that introductory courses in statistics, even when taught by people whose primary competence and interest is in some other field; have been steadily improving over the past few years. This is due primarily to the fact that younger men in these various subject matter fields have been receiving better training in statistics. Statistics will never be taught satisfactorily in our colleges by instructors who themselves have not been taught the fundamental statistical concepts in a precise manner, and have not acquired an appreciation of their full generality.

Value of Statistics is Recognized

Many biological and social scientists have been cognizant of the need for statistics for many years, and have included basic and advanced courses in the field of statistics in their educational program. The physical scientists, representing such disciplines as physics, chemistry, and engineering, have been so dependent on traditional courses and concepts that they have been relatively hidebound and hand-tied in accepting statistics as an important ingredient in either basic or advanced training in these fields. Professor S. S. Wilks, in a talk given at the meeting of the Mathematical Association of America, August 28, 1957, made the following comment:

> "One of the outstanding examples of an unfilled need for some training in probability and statistics is in engineering education. The statistical quality control movement which started during the War and which has pretty well permeated American industry caught the engineering profession completely untrained in even the rudiments of probability and statistics."

If it had not been for the American Society for Quality Control, and a handful of statisticians who organized and conducted the popular short courses for the practicing engineer, statistics in industry would still be in its infancy, providing it had been born at all. Although these short courses have been, and continue to be, extremely valuable in filling a void in engineering education, a more potent remedy than "short courses" will have to be applied if statistics in industry ever gets out of knee pants. In a private conversation with Dr. George Snedecor about 10 years ago he made the remark that the short courses in industrial statistics would set statistics in industry back twenty-five years. I didn't agree with him, at that time, for I was thinking of the short run. But now I am beginning to wonder if he saw that the short courses would lull the engineering and physical science educators into thinking that statistics for industry could be taught on the job, in a relatively short time, and by almost anyone with a smattering of statistical training.

Industry is to be complimented for its effort to supply training to its employees in the field of statistics. But is this the role in the teaching of statistics and in the training of statisticians that industry desires to play in the long run? If the programs in statistics in our educational institutions are not enlarged and improved, industry will have no alternative but to continue to teach its old employees and every new employee from now on.

Has industrial statistics been reduced to a few simple routine techniques, such as control charts, and sampling plans? If this were the case, I would be among the first to suggest that courses in statistics should be deleted from any curriculum which is designed to train people for industrial employment. Of course, we know that this is not the case. At the present time a very critical look is being taken at the engineering curriculum and there seems to be a trend towards a program aimed at producing engineering scientists rather than just engineers. However, there is no program that will permit an educational institution to turn out graduates who will not need considerable orientation and additional training for specific jobs in industry. In fact, many of the things now being taught in college and the university physical science programs could be deleted from the curriculum and delegated to the "in-plant" training program of industry. The job of the university is to provide leadership, training, and inspiration for the development of scientists in all fields, and this includes engineering science. It is the responsibility of industry, by the use of their in-plant training programs, to develop technicians. Industry can do a better and more economical job of keeping their technicians abreast of the rapidly changing technology than can our educational institutions.

Although the supply of statisticians is limited, there is some evidence of the misuse of people trained in statistics. An individual trained in statistics may perform a very creditable piece of work in many other job assignments. A practicing statistician is in position to become acquainted with the objectives and policies of an organization wherein he is employed, and thereby becomes a good bet for supervisory, research, or advisory positions. The moment he does accept such a job he usually finds little direct use for his statistical training. However, he does encourage the use of statistics in the organization and thereby tends to further widen the breach between supply and demand.

Let's Not Stop at Control Charts

Up to this point I have indicated that the shortage of statisticians is due to increasing demand for statistically trained personnel and the inadequate statistical training programs in our colleges and universities. I have also stated that I cannot foresee any major change in this dilemma (1) until our educational leaders and administrators are willing to give statistics the status of a separate discipline, (2) until statistics courses, including the introductory courses in each and every department, are taught by instructors who themselves have been taught the fundamental concepts in a precise manner, and (3) until industrial leaders recognize the limitations of the popular short courses and begin to make their wants and needs in the field of statistics known to the educators and administrators in educational institutions from which they draw their employees.

Let us now turn to the organization and role of a statistical center in an educational institution. Of course, there is no one program which is so unique that it will operate as an optimum program at all institutions. There are many alternative organizations that any given institution may adopt with equal success. A complete statistical center can best be developed in those institutions which are designed for a graduate program. A complete statistical center should provide the following: (1) a research and teaching program leading to a career in statistics, (2) a service teaching program, (3) a consulting service program, and (4) a computing service program. I shall comment briefly on each of these.

The research and teaching program should be designed to develop professional statisticians. It should involve the teaching of the theory and methods of statistics in parallel courses all the way from the introductory courses to special topics on the frontier. It would involve basic research in theory and methods in statistics. A strong mathematics department would provide the necessary mathematics courses to develop a well-rounded statistician.

A candidate for the Bachelor of Science (B.S.) degree should be encouraged to obtain as broad an education as possible including courses in the biological, physical, and social sciences. Basic training in college mathematics should include courses in advanced calculus, matrix algebra, and numerical analysis. A minimum of three year-courses in the theory of statistics and statistical methods would provide a strong undergraduate program. A candidate for the Master of Science degree should have in addition to the above courses a one-year course in statistical methods and a one-year course in theory of statistics which should be supported by work in advanced calculus, modern algebra, theory of probability, and numerical analysis. A candidate for the Doctor of Philosophy degree should have in addition to the above a year-course in modern statistical methods, two year-courses in theory of statistics, and supporting work in mathematics such as complex variables, modern algebra, and numerical analysis. Seminars, special problems, and the preparation of a thesis form an integral part of an advanced degree program.

The service teaching program should be designed to provide the basic courses in both theory and methods for students majoring in some subject matter area other than statistics. The curriculum of every college and university should include an introductory course in statistics. Such a course should form an integral part of a general education, and it should be taught in such a way that it would interest a few promising young students in statistics as a profession. Specialized courses for students majoring in areas other than statistics should be provided. Such courses will be best taught by those who have a primary interest and competence in the field of statistics and a secondary interest in some other appropriate subject matter area. For students in areas other than statistics, it may be necessary to present the subject matter area of statistics from an intuitive and non-mathematical approach and this can best be done by: (1) one who understands the underlying assumptions and limitations, (2) one who steers clear of the many pitfalls, and (3) one who can inspire and direct the student to go beyond the classroom in his search for statistical tools appropriate to his field of interest. This type of service teching should not be made a corrolary to the career program. However, it is a much stronger program when the institution has a graduate program in statistics.

The development of a consulting service is almost impossible without a parallel development of both a career and a service teaching program in statistics. The consulting service program should provide an opportunity for the research workers on a campus-wide basis

to discuss their investigations involving the use of statistical theory and methods. This program should also provide a training ground for consulting statisticians. It is from this area that an institution is able to serve beyond the confines of the campus by consulting with industries or government agencies in the region when the service is required, requested, and justified. This off-campus service not only renders a valuable service to our state and nation, but, in return, the program in statistics is enriched by academic contact with a wide range of very interesting problems.

The computing service should provide for the analysis of data resulting from the consulting service program referred to above. A computing program provides both service and training. It provides a service by relieving the professional staff of routine tasks while giving training to student statisticians. Although computing is an essential part of statistics, it is not necessary, or desirable, to use highly trained statisticians to perform such service. Routine computing can be handled by clerical personnel with a minimum of supervisory help. High-speed computing service to the research staff of the institution should be provided in some feasible manner, but it is a misuse of limited statistical manpower to use trained statisticians to man such equipment.

Summer Institutes Established

In 1952 and 1953 the Southern Regional Education Board held a series of conferences, attended by representatives of a large number of colleges and universities in the fourteen Southern states, to study the problem of statistics in the South. Based on an intensive survey of the teaching of statistics in the Southern colleges and universities, and the findings of several study groups of this conference, several suggestions and recommendations resulted in establishing a graduate summer session in statistics for the Southern region. Based on these recommendations and inspired by an intense interest in the development of statistics, four institutions, North Carolina State College, Virginia Polytechnic Institute, University of Florida, and Oklahoma State University, entered into an agreement to operate a continuing program of graduate summer sessions in statistics to be held at each institution in rotation. The purposes of this program are to serve (1) research and professional workers who want intensive instruction in basic statistical concepts and modern statistical methodology, (2) teachers of elementary statistics courses who want formal training in modern statistics and probability, (3) graduate students in fields other than statistics who desire supporting work in statistics, (4) prospective candidates for graduate degrees in statistics, and (5) professional statisticians who wish to keep informed about advanced specialized theory and methods.

It was agreed that each of the sessions would run for six weeks and that a maximum of six semester credit hours could be earned at each session. The curriculum is composed of nine hours of theory of statistics, nine hours of statistical methods, six hours of mathematics, including advanced calculus and matrix algebra, and a wide assortment of special courses both theoretical and applied. The program may be entered at any session and by attending successive sessions it is possible to complete course work in statistics for a master's degree in statistics. The summer work may be applied as residence credit at any one of the co-operating institutions, as well as certain other universities, in partial fulfillment of the requirements for a graduate degree. Students must satisfy the remaining requirements for course work and thesis at the institution where they are admitted to candidacy. The advanced courses may be accepted as part of the Ph.D. program of the participating institutions.

The attendance at the previous summer sessions has averaged about ninety, including representatives from every one of the forty-eight states. Many foreign students, studying for degrees in our country, have availed themselves of these special summer sessions. It is interesting to note that an increasing number of industries are participating in these sessions. An incomplete survey shows that representatives from chemical, pharmaceutical, steel, petroleum, aircraft, and electrical industries have attended. Although the majority of the enrollment has consisted of students pursuing a course of study in statistics, representatives from medical research institutes, Army and Navy research installations, and such other government agencies as the Bureau of Mines and U. S. Department of Agriculture have attended. We have been disappointed in the response of teachers of statistics to this special summer session. It is hoped that someday the National Science Foundation, or some other foundation, will support an institute for the training of teachers of statistics similar to the programs for mathematics and science teachers.

Training Possibilities Suggested

I have talked to many of my friends in industry concerning the most economical and efficient way for industry and educational institutions to co-operate in this business of training statisticians for industrial employment. The two ways mentioned most frequently in which this might be accomplished in the short run are: (1) the short course technique, and (2) the in-plant training program. The short course technique is frequently sponsored by the American Society for Quality Control, and conducted by some extension division of one of our universities. It has been extremely useful in the area of control charts and inspection sampling, and has been instrumental in introducing some statistics into the engineering education curriculum. The in-plant training program in statistics in some companies has been quite successful. The summer employment of graduate students and teachers has been mutually beneficial. However, due to the shortage of personnel within the companies who are qualified to direct such training courses, it has been far from adequate. I have heard this in-plant training program referred to as "Operation Bootstrap." Both of these programs should be continued, but it is hoped that both courses could be organized and conducted at a much higher level and with a much stronger prerequisite.

However, to solve the twin problems of too few statisticians and too little statistics in industry, it will be necessary in the long run to have more than short courses and in-plant training programs in statistics. I would like to suggest two possibilities: (1) a program which will take personnel now in the employ of industry and send them to some qualified statistical center for at least a year of concentrated study in statistics (an alternative to this year-program is to take advantage of the Southern Regional Graduate Summer Sessions in Statistics), and (2) a program which will establish the need for statistics in the minds of educators concerned with engineering education and with the physical science curriculum. This may be done either directly or indirectly. Educational and industrial leaders have many joint conferences on educational problems. Instruction in statistics should be a topic at such conferences. A

basic objective of every educational institution is, "serve the needs of the state and nation." Every educator I know will welcome assistance in identifying these needs. This would be the direct approach. Industry could also show its need for statistical training in our educational institutions by establishing scholarships for undergraduates in the physical sciences with the stipulation that courses in statistics be added to their plan of study. However, regardless of the method, the identification of the need for statistics must be established in the minds of the curriculum makers in the area of the physical sciences. Statisticians cannot do this job by themselves!

Instrument Calibration Scheduling

simplified with electronic data processing machines

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Accurate, reliable calibration of electrical testing equipment is a prerequisite to quality production in modern industry. However, the actual work of calibration is of secondary importance in the smooth functioning of a Calibration Department. While skilled technicians and well-equipped laboratories may adequately fulfill technical requirements, comprehensive calibration programs present problems in logistics and record keeping which are of prime concern.

The most pressing problem in such programs is the requirement for obtaining a smoothly-operating scheduling system which can provide for the handling of thousands of pieces of test equipment on a periodic basis. Whatever scheduling system is employed, it must provide essential information such as the equipment manufacturer, the model of equipment, the identification numbers, the plant location, etc.

Within the Calibration Department, the daily allocation of individual work assignments is an additional scheduling requirement. An even flow of equipment through the department and back to its original location must be assured. This means that information, such as the individual performing the calibration, time spent, maintenance record, etc., is essential for operation analysis. By standard methods, however, this collation of data requires excessive clerical personnel. It also infringes considerably upon the productive time of technicians who must provide the necessary data for record purposes.

EDPM Methods Applied

Any effective scheduling system for a calibration program must fulfill the aforementioned essential requirements with a minimum of actual record-keeping by department personnel. Such a goal has in great part been achieved by the application of Electronic Data Processing Machine (EDPM) methods to the scheduling operations of the Calibration Department at IBM Kingston.* This department is currently handling approximately 6500 pieces of varied test equipment on a periodic basis with an average calibration period of 30 days. The system also has provisions for handling semi-monthly, bi-monthly, tri-monthly, semi-annual, and annual scheduling. This versatility provides a schedule program applicable to any type of test equipment.

A secondary benefit derived from this scheduling system is a complete, accurate accountability listing of all equipment. This listing makes possible a complete inventory in a relatively short time. The system also permits a complete schedule of the department's work load for a month in advance, exclusive of unscheduled work. All unscheduled work must be reported on a blank IBM card (one for each piece of equipment) and can form the basis for determining what percentage of the departmental work load is in the nature of unplanned work. Thus, the personnel requirements of the department can be accurately established.

With the new scheduling system, a minimum of clerical work is required from technicians. The system also provides essentially automatic individual work assignment within the department. Accurate maintenance records which take into account time and parts consumed as well as malfunction diagnosis and remedies applied can now be kept. Departmental operations may also be analyzed from the data in all of the compiled reports.

A minimum of clerical help is required for maintenance of the scheduling system, which also provides a monthly running inventory. At the present time, one clerk handles a volume of approximately 6500 pieces of test equipment per month. In addition, he has charge of the other clerical duties such as ordering, distributing, and maintaining stationery supplies for several departments as well as initiating requisitions and filing.

Schedule Period

In order to understand the scheduling system as it is currently functioning at IBM, some familiarity with the schedule period is mandatory. The calibration period is basically 30 days, with provisions for scheduling at one-half this frequency or in multiples of 30 days such as bi-monthly or tri-monthly, etc. The entire work load of the department is distributed as equally as possible over this 30-day period.

*The Methods Department at IBM-Kingston has been of assistance in the design of the card forms used.

Requirements of individual departments using test equipment must, of course, be borne in mind when scheduling the work load.

All equipment is assigned a permanent calibration due-date from 1 through 30. No equipment is scheduled on the 31st day of any month. This method also schedules equipment on Saturday and Sundays which are normally non-working days. Obviously, equipment falling due on these days must be distributed over the work loads for Friday and Monday. Equipment schedules for February would be on a 30 day basis, the same as for any other month, however, the equipment due on the 29th and 30th of the month would be handled on the 28th of February or the 1st of March, in addition to the routine scheduled for these days. During a leap year, only one extra day's work would have to be accommodated, this on the 29th of February or the 1st of March, in addition to the scheduled routine. Initially, scheduling equipment in this way might seem a severe disadvantage, but in practice it has caused a negligible amount of trouble when the advantages gained are considered. Any method of scheduling other than fixed due dates does not appear to be feasible in this application of EDPM techniques.

Calibration Master Cards

A Calibration Master Card, shown in Fig. 1, is originated for each piece of equipment, and bears the following information:

1. Four-letter abbreviation of Vendor's name.
2. Vendor number, consisting of a six-digit code coinciding with the vendor code used by the Purchasing Department.
3. An identification number (ten-digit code) provided by the Air Force to identify Government Property.
4. A two-digit model code, compiled for all models of each vendor's equipment.
5. A three-digit Using Department code number.
6. A location code (one-digit) specifying which section of the Calibration Department is responsible for performing the work.
7. An "X-Two Inspection Unit Number"—marked with an X if unit is to be calibrated bi-monthly.
8. Two-digit number indicating day of month due.

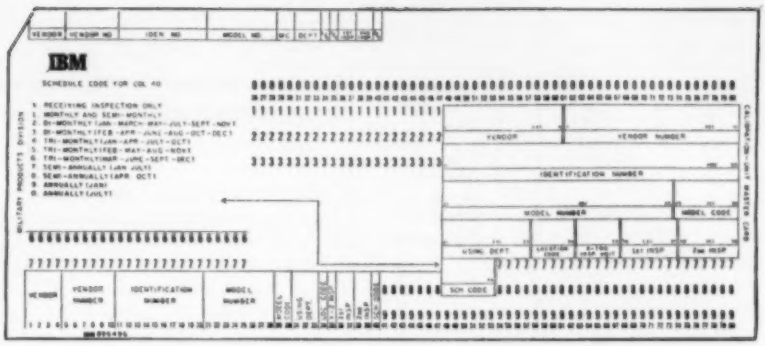


Figure 1—Calibration Unit Master Card, IBM 896496

9. Two-digit number which shows day of month due for second inspection (if required).
10. One-digit schedule code—refers to code for column 40 on the face of the punched Master Card.

The above information is first entered on a blank Master Card as source information. It is then key punched into the card and can be machine processed by an EDPM which senses the key punches.

When coding column 40 (item 10 above) the "Schedule for Col. 40" in the upper left portion of the Calibration Unit Master Card (Fig. 1) is used. The information is used primarily by the Machine Accounting Department, which performs the required machine processing, to select the cards required to prepare a monthly schedule. The Calibration Unit Master Cards are submitted to Machine Accounting on a mutually agreeable date to be processed for the succeeding month's work schedule. Thus, the "Schedule for Col. 40" indicates which Master Cards are required for processing. For example: a master card containing the digit 4 in column 40 would be submitted to Machine Accounting to be processed for April's work schedule. The Schedule Code indicates that all master cards coded 1, 3, 4, or 8 will be required to prepare the desired schedule. A machine sorting procedure on Col. 40 would select all the cards punched with a 1, 3, 4, or 8 digit. The master cards selected would then be used to prepare the actual April schedule. Thus, the example card assures that a schedule card for the applicable instrument will appear in the April schedule.

The assignment of a schedule code and due dates is the responsibility of the instrument crib clerk, who determines these dates from existing schedules.

As additional equipment is received, Calibration Master Cards are originated and accumulated until approximately the 20th of the month, when they are sent to the Machine Accounting Department for keypunching, interpreting, and collating into the existing deck of punched cards. Calibration Work Cards for the following month are processed from this deck of punched cards.

Calibration Work Cards

Calibration Work Cards, a sample of which is shown in Fig. 2, are obtained by transferring information from the Master Card into corresponding columns in the Work

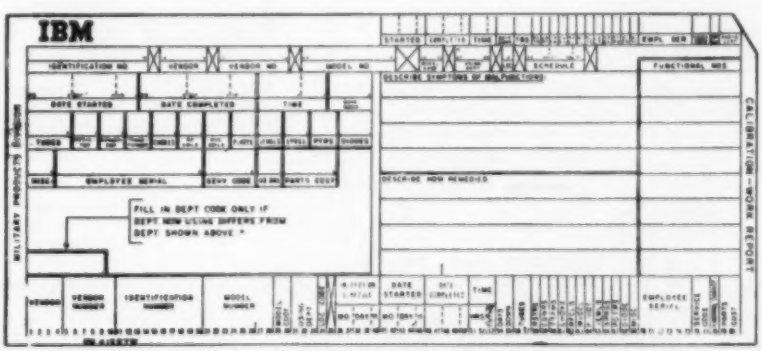
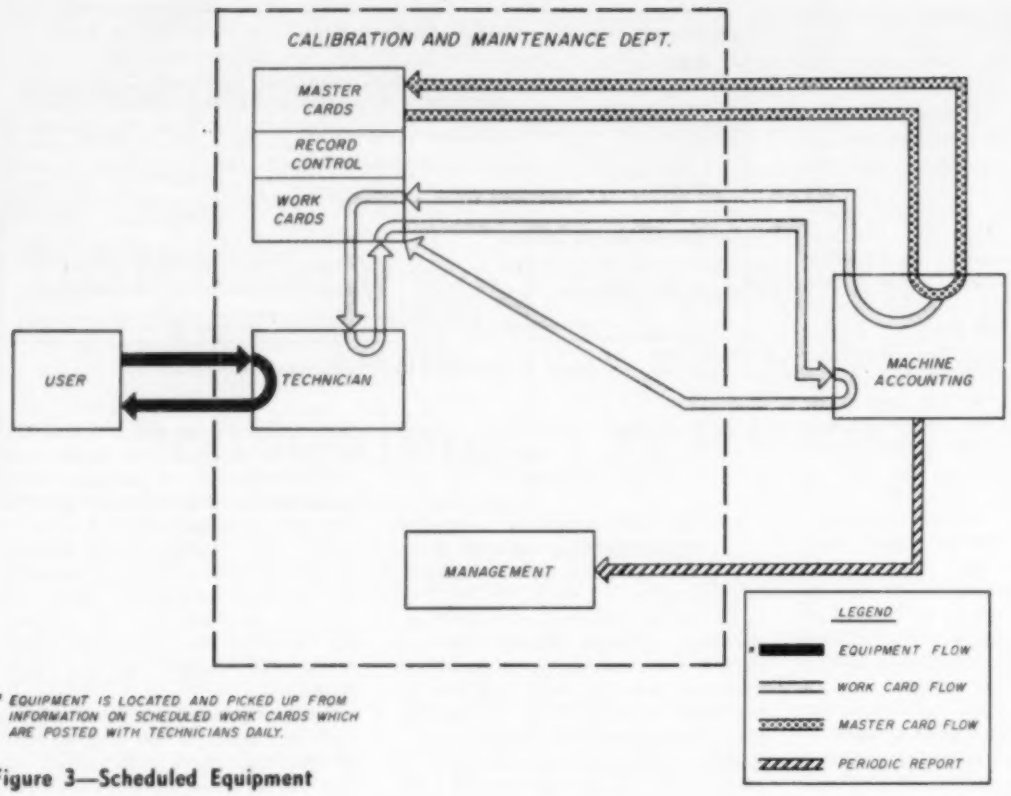
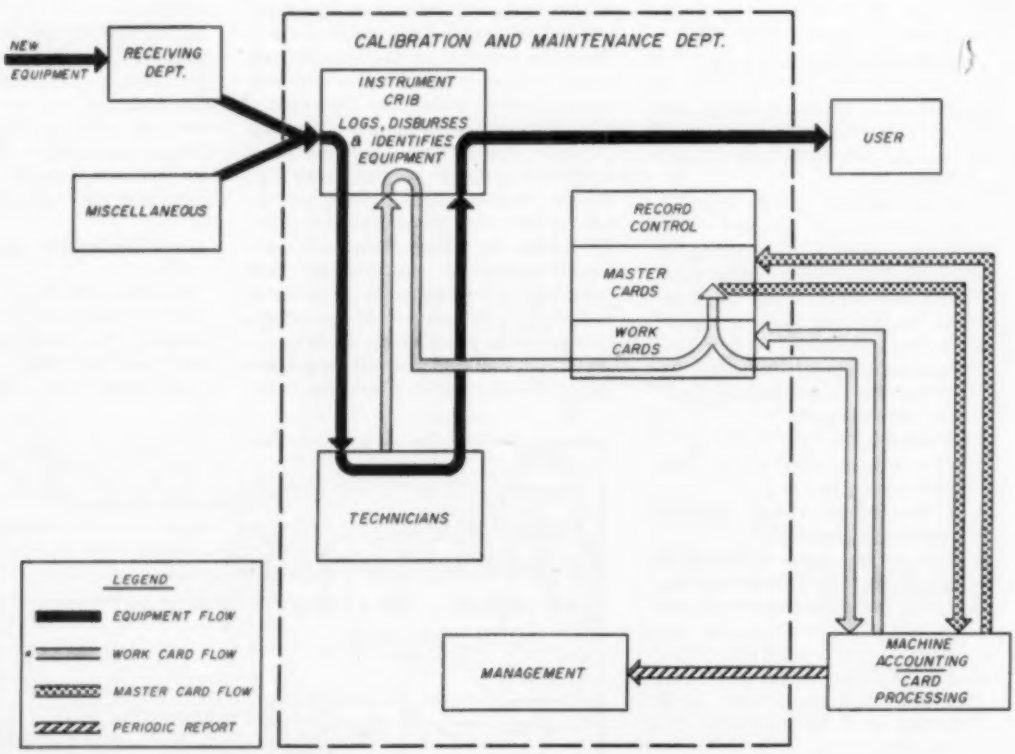


Figure 2—Calibration Work Report, IBM 415279



* EQUIPMENT IS LOCATED AND PICKED UP FROM INFORMATION ON SCHEDULED WORK CARDS WHICH ARE POSTED WITH TECHNICIANS DAILY.

Figure 3—Scheduled Equipment



* ON UNSCHEDULED EQUIPMENT, THE WORK CARD IS ORGINATED BY A TECHNICIAN FROM AN UNSCHEDULED BLANK WORK CARD.

Figure 4—Unscheduled Equipment

Card. This is a rapid, machine process which results in an accurate, complete Work Card file for the month concerned. After Work Cards are obtained, both the Master Card file and the resulting Work Card file are returned to the Calibration Department, in separate files, sequenced numerically by I. D. numbers. The Master Card file thus forms a permanent accountability file for all equipment, while the Work Card file represents the complete scheduled work load of the department for the forthcoming month. Figure 3 is a flow diagram of scheduled equipment.

The information interpreted on the Work Card consists of the following:

1. Vendor
2. Vendor Number
3. Identification Number
4. Model Number
5. Model Code
6. Using Department
7. Location Code
8. Inspection Schedule

These Work Cards are then collated by Location Code and day of the month. A schedule sheet (a portion of which is shown in Table I) is then prepared in multiple for distribution to all departments so that they can anticipate removal of equipment for calibration. The collated Work Cards are returned to the Calibration Department in time to start distribution on the first day of the following month.

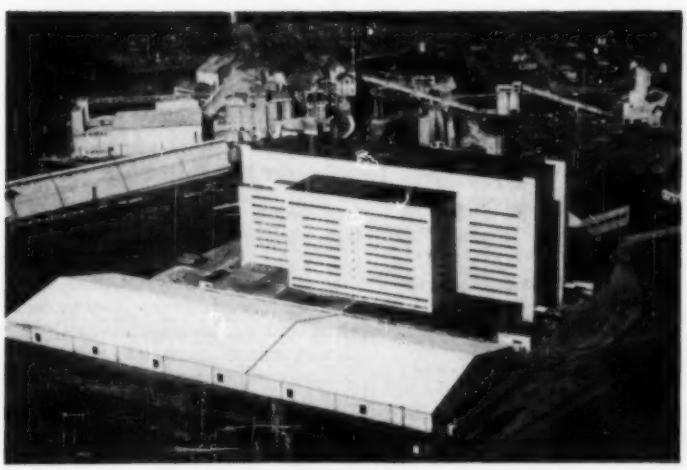
TABLE I—Sample Monthly Schedule Sheet Entries

Location Code	Schedule Date	ID No.	Using Dept.	Vendor	Vendor No.	Model No.
7	10286	2116805350	548	TRIP	910670	631
7	10286	2116808799	548	LBDA	535230	50
7	10286	2116812545	515	WEST	962541	622

Starting on the first day of the month and each day thereafter, the applicable Work Cards for each location in the Calibration Department are posted in the "Scheduled" section of a card rack and indicate the work assignments for the personnel in that location. In order to effectively distribute the Work Cards to the section of the Calibration Department responsible for the performance of the work required, each section is equipped with a three compartment card rack. The rack is identified with the department section number and each compartment is identified as "Scheduled," Working," and "Done" respectively. The cards are advanced from the Scheduled compartment through the Working compartment to the Done compartment by the technicians as they perform the work required. Work Cards for the equipment being calibrated are placed in the "Working" section of the card rack. Each technician completes the applicable Work Card for the piece of equipment calibrated by entering the following information on the card:

1. Date Started
2. Date Completed
3. Time
4. Day Down
5. Description of Malfunction Systems
6. Description of Repairs
7. Itemized quantities of parts used and part numbers from applicable schematic diagrams.
8. Employee Serial Number
9. Proper classification of unit under Service Code, 01 through 99, which has been established

Quality Control Begins with Research and Development



Through the statistical approach to quality control and progressive development, Johns-Manville has zealously maintained its reputation for quality.

J-M Asbestos Mill World's Largest

As evidence of this research and development Johns-Manville announced late in 1954 the dedication of what would be the world's largest asbestos mill. In fact, this mill when only half completed was the largest in the world. It is now completed and in full operation.

Illustrated here is the mill building located at the J-M Jeffrey Mine at Asbestos, Canada.

Through rigid quality control and the most modern equipment for the milling of high quality asbestos fibres, Johns-Manville is meeting the increasing demands for the higher grades constantly required for new product developments for both home and industry.

Providing a production capacity of 625,000 tons annually, this recently completed asbestos mill provides twenty-two and one half acres of floor area, is 12 stories high. Additional capacity will be added in the near future.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville

22 EAST 40TH STREET NEW YORK 16, N. Y.

to permit a uniform classification of the equipment status.

10. Indicate X in abnormal damage space if such damage was encountered and describe on reverse side of card.

These cards are picked up daily from the "Done" section of the card rack and are sent to Machine Accounting for keypunching, interpreting, and collating by identification number. The cards thus form a permanent record of all calibration work done and are available in this form for compilation of reports for analytical purposes.

Incoming Test Equipment

New test equipment is processed through receiving inspection function of the Calibration Department to determine whether it is acceptable. All equipment that meets inspection standards is then sent to the instrument crib where it is brass-tagged and entered on the instrument crib log sheet. Calibration Master Cards are then originated for each piece of test equipment. The diagram in Fig. 4 illustrates the flow of new and unscheduled equipment through the Calibration Department.

Conclusion

Any form of scheduling involving large quantities of mobile test equipment is dependent upon close coordination between the calibration department and the department using the test equipment. Problems arise primarily because of human failures to achieve the necessary cooperation between departments. Obviously, equipment cannot be permitted to be moved about indiscriminately. Test equipment must always be moved through the accountability channels set up. If the scheduling system is not adhered to implicitly the results will be less than satisfactory in proportion to the amount of laxness allowed.

In the area of management reports which can be obtained quite systematically and painlessly via EDPM, the information required is largely a function of management interests. Because of the range of information which can be made available in punched card form for machine processing there is actually little limitation to the type of report which can be made. The information is presented in printed form in accordance with the requirements of the information requested, providing optimum efficiency of analysis.

In the system described, for example, the maintenance costs involved in maintaining and calibrating the equipment of a specific vendor might be compared with the costs of performing similar functions on equivalent equipment of a second vendor. The versatility contained in the application of EDPM techniques thus provides management with an efficient tool which permits adaptation to specific requirements in a manner which cannot be provided in any other way.

quality control as an Administrative Aid

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Introduction

The higher one looks in administrative levels of business, the more likely one is to find that decisions are based on tabular or graphic presentations of data. It is apparent that at the administrative level, at least, one of the principal methods of contact with the rest of the organization is through statistics. This is so well recognized that in some large organizations, "Chart Meetings" are a part of the regular routine at administrative levels.

What this means from the viewpoint of quality control is that when top administrators realize what it is all about, not only does quality control begin to roll on the production line but also it begins to find uses throughout the business structure.

Extent of Administrative Application

The use of quality control methods to help solve administrative problems, therefore, has come about naturally. Actually, although administrative applications have not been as numerous nor as spectacular as those to production quality, there has been a steady, parallel growth, even from the earliest days of statistical quality control. Over 70 literature references were listed during research for a paper[1] on management uses of statistics and the literature has continued to grow steadily since then.

Clerical operations have offered some of the best opportunities for application. This is logical, because the products of clerical operations, although paper reports, are quite similar to manufactured products in that they lend themselves to sampling and charting techniques. It is remarkable to note the almost immediate improvement in quality of clerical operations after the installation of control charts to determine levels of performance. There can be little doubt that the application of quality control principles has brought about these improvements. This is true because when well designed, the control charts strip out differences between individuals or operations. Acceptable performance criteria are stated in advance of starting work. Reports are rendered, usually in the form of "p" charts, so

that quality levels are known to all and intelligent decisions follow naturally. This is an improvement over the kind of situation which used to prevail in which the requirements of the job were not clearly explained to the workers and no systematic check was made to help the worker keep his work in line. Accounting records, inventory counts, or auditing records also lend themselves readily to quality control procedures. As a matter of fact, it is difficult to think of any activity of management that cannot be improved by some application of quality control techniques.

Applications to Inventory Control

One type of administrative application that has not received much publicity is the study of inventory control problems. It is granted that the total problem of inventory control involves considerations which are outside of what is understood generally to be the field of quality control. As a matter of fact, inventory control problems have occupied a significant part of the attention of workers in the related field of operations research. However, there are parts of the central problem of inventory control, as well as many related problems in data analysis, to which quality control techniques may be applied profitably. In particular, quality control can be extremely useful in measuring and improving the homogeneity of the data being used in an inventory control study. As an example, a study of the quality of warehousing records may be cited.

Warehouse Stock Control

A physical inventory in a certain warehouse revealed that the amount of stock on the shelves and the stock card record of what should be there were in disagreement for about 80 percent of the items carried. Preliminary investigation of this situation indicated that arithmetic errors in recording transactions on the stock cards was one of the major difficulties. Errors were also occurring in placing re-stocking orders on the plant and in billing of sales to customers.

Accordingly a technique was devised for sampling of paper work at points where most errors were occurring and for control chart analysis of the results. The four principal checks that were established are described as follows:

1. *Errors on stock cards.* Daily, during the first 14 working days of a trial month, all cards involving re-orders, plus a random selection sufficient to bring the sample up to 25, were examined for errors (arithmetic, transposition of figures, over-order, or under-order). The error rate was 10 percent. The average number of errors per day was 2.36. When arithmetic and transposition errors were grouped, the average number of errors per day was 1.43. The upper control limit for this type of error is 3. That is, based on experience, a normal day could be expected to show 3 errors. There were days that exceeded 3 errors and these were "out of control," that is, they were exceptionally worse than usual. When errors involving over— and under—orders were grouped, the average number of errors was 0.93. The upper control limit is 2.

Analysis of the sources of these errors on out-of-control days armed the manager with the necessary information on what needed to be done to reduce the rate of error to a more satisfactory level. In part, this seemed to be a matter of use of psychology and encouragement. In part, it involved further training of the individual workers to use care in use of price lists and other information sources. In part, it was subject to correction by improvement in procedures, such as the suggestion that the total number of items in each order appear on each piece of paper connected with the order.

Progress was measurable in terms of further reduction in the over-all error rate or in terms of decreasing the control limits.

The initial reason for instituting the check on stock cards was to uncover arithmetical errors. It was found by careful checking of stock cards selected at random from the files and also of stock cards up for re-order, that it was possible to control the inventory re-order system very effectively. This was shown up quite dramatically by the drop in total inventory dollars at cost by 27 percent over a four month period. This lower inventory figure was achieved with no stock run-outs.

2. *Check of Cards Against Physical Stock.* During the sampling period of 14 days, five cards picked at random and checked against actual stock showed no discrepancies. This period immediately followed a complete inventory, however. This check was dropped for the time being but the manager will run a series of similar checks quarterly.

Since the stock has been completely inventoried and handling procedures have been reviewed and improved no difficulties in keeping the records straight are anticipated.

3. *Check of Billing Errors.* Sampling of bills uncovered only very infrequent typing errors and these could be explained by the fact that the office was breaking in a new typist. The typing errors should decrease in number as the typist becomes more experienced.

An analysis of credits showed that the majority of them were due to incorrect quantity discounts being applied. Any checks made on the billing would not uncover an incorrect quantity discount. The solution was to have the total ordering quantity appear on all parts of an order. When a spot check is run on the billing it will then be possible to ascertain whether or not quantity discounts are being applied correctly.

4. *Errors in Orders Placed on Plant.* By a systematic supervisory review of all orders the manager was able to reduce the error rate on restocking orders to the plant from 15 percent to 2.5 percent. Naturally, it is desirable to be able to relax this type of review and it may be possible when the original error rate has been reduced by use of good psychology, training, and procedure improvements.

The time required to do the checking involved in the program described amounted to approximately two hours per day. This seemed excessive and a more reasonable time has been arrived at by checking only stock cards up for reorder (an average of 15 cards are looked at and the checking time involved is about one-half hour). The card versus stock check as well as the check on billings have been eliminated temporarily. These will be reinstated periodically. Orders on the plant are still being checked thoroughly.

The method of checking a representative sample and analyzing the results to establish control limits which can be applied to any one day's production has justified the time required to do so in the case of stock card and re-order points. In the words of the manager, the results obtained certainly indicate that the warehouse cannot relax these checks and still maintain the control required.

Maximum Size of Inventory

Some time ago, the author was involved in a determination of maximum inventory size for a distribution operation of considerable size. This operation involved twelve different products distributed from four warehousing points in the East

and Middle West. A great deal of the study involved, of course, the enumerative approach ordinarily thought of as the domain of the business statistician. However, very critical parts of the analysis of the data were accomplished, in this instance, by the use of Shewhart control chart principles. Still other aspects of the study were amenable only to an operations research approach. It is intended in this discussion to cover only the part which quality control chart concepts contributed to solution of the total problem.

The products were bulk materials shipped in drums and accounting was made on the basis of the pounds shipped. Data were available for at least twelve months, in some instances for as many as 18 months, on the number of pounds of each of the twelve products shipped from each of the four warehouses.

The first column of figures in Table I shows the total actual monthly shipments of a typical product from one warehouse. Obviously, these figures vary so much that no sound statistical forecast could be made on the basis of these data alone. Actually, in the past, inventory levels had been established on the basis of accumulated forecasts by sales territories. This was generally unsatisfactory, however, partly because of the perennial optimism of salesmen, partly because no really systematic use of data was being made to determine maximum inventories, and partly because warehouse districting was in need of revision. It had been common practice to tranship between warehouses or to ship across warehouse district lines to fill rush orders. As a result of these undesirable conditions, the over-all turnover during the most recent period had been only 3.3 times per year.

As a first step in the analysis, it was decided to reallocate all shipments for the period for which data had been accumulated on the basis of the logical shipments from each warehouse. A logical shipment was one which minimized the shipment cost and eliminated the need for transhipments from warehouse to warehouse.

In making this reallocation it was decided that a considerable portion of the total shipments, including all car lot shipments, could be made directly from the plant which was located near one of the larger centers of use, without intervening warehouse storage. The resulting logical shipments for the typical product used as an illustration are given in the second column of Table I.

The variation in logical shipments was much less than in the actual shipments and some statistical analysis seemed possible. Accordingly, for each set of data, control chart limits were computed based on the moving range of consecutive monthly figures. Typical range computations are given in the final column of Table I. Control chart limits for individuals and ranges were then computed, as follows:

Individual limits: $\bar{X} \pm E_2\bar{R}_M$
$= 17{,}007 \pm 2.66 \times 6839$
$= 17{,}007 \pm 18{,}192$
$= 35{,}199$ and 0

Range limits: $D_4\bar{R}_M$ and $D_3\bar{R}_M$
$= 3.267 \times 6839$ and 0
$= 22{,}343$ and 0

These are very wide limits due to the variability still present in the estimates of logical shipments, but they do indicate that it is not too unrealistic to use the moving range data to determine maximum inventories, at least on a preliminary basis. It was decided that in each case an inventory should be maintained capable of meeting 90 percent of the demands on the warehouse. The standard deviation of the logical shipment data from Table I is given by $s = \bar{R}_M/d_2 = 6839/1.128 = 6063$ with 12 degrees of freedom. An upper bound which will guarantee meeting 90 percent of the demands is given by

$$\bar{X} + ts = 17{,}007 + 1.78 \times 6063 = 17{,}007 + 10{,}792 = 27{,}799.$$

This was rounded downward to 27,000 pounds which is considered to be the maximum inventory figure. This gives a turn-over rate of 7.5 times per year compared to the old over-all rate of 3.3. If there had been a marked trend in sales volume or if sales had fluctuated seasonally, it would have been necessary to apply appropriate corrections. However, this was not done and when the maximum inventory levels had been obtained as described for each material at each warehouse, the total maximum inventory at the four warehouses turned out to be 417,000 pounds compared to the previous peak inventory of 681,500 pounds, a reduction of 39 percent. The new turnover rate was estimated as 4.0 times per year compared to the old rate of 3.3. Furthermore, the total annual volume handled by the warehouses was reduced by 38 percent due to the practice of shipping to the local area or elsewhere by car lots direct from the plant.

Control charts, like the one for the example shown in Fig. 1, portrayed all of the pertinent information graphically and assisted in the analysis of each situation.

No system may be devised which will work perfectly under all conditions and it was expected that this system would be subject to adjustment upward or downward for known seasonal fluctuations or for unusual changes in normal orders during a given month.

TABLE I—Total Shipments in Pounds, Warehouse 1—Product H

Month	Actual Shipments	Logical Shipments	Moving Range
July	16,650	11,700	
August	11,250	11,700	0
September	44,100	19,800	8,100
October	13,050	15,766	4,034
November	30,600	25,200	9,434
December	24,300	11,700	13,500
January	40,500	27,000	15,300
February	12,150	28,350	1,350
March	36,450	18,000	10,350
April	29,250	8,675	9,325
May	19,350	16,200	7,525
June	29,700	13,950	2,250
July	31,950	13,050	900
Totals	339,300	221,091	82,068
Averages	26,100	17,007	6,839

Applications to Rating of Personnel

The analysis of merit rating is an application in which useful information is often turned up, not only about the persons rated but also about the supervisors doing the rating[2]. This is the case in the following example which discusses

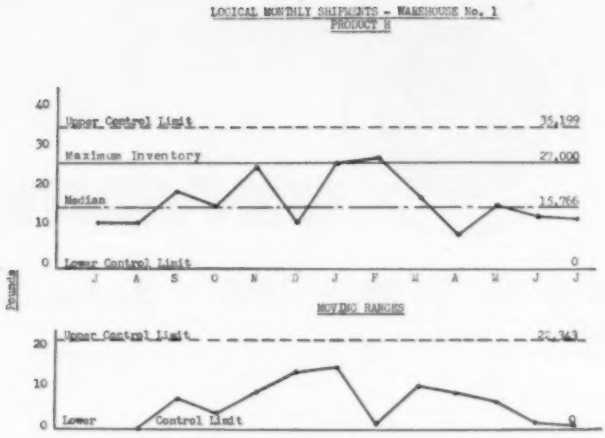

Figure 1—Control Charts for Inventory Control

the rating of a large group of technical employees.

Comparison of Ratings of Technical Personnel.

The 309 technical people employed in a research laboratory were assigned to one of nine groups, each under a group leader and from one to three assistant leaders. In applying a standard merit rating plan, the supervisory personnel were rated by the director of the laboratory and each group of researchers was rated by its own group leader or leaders. One final score, on a scale between 0 and 1200, was assigned to each individual. With this many raters involved in rating so many groups, many variations in the ratings are to be expected. One rater may rate all individuals in his group too high, another too low. A rater may be prejudiced and rate certain individuals high and others low. Furthermore, in any given group there may be individuals with qualities either far exceeding or much lower than those normal for the group or required for the type of work being done.

Comparisons may be made within each group or a standard for the whole laboratory may be determined and all groups compared to it. This latter is undoubtedly the best thing to do in this instance since the work of all the groups is very similar. However, as a first pass at analysis of results, the ratings for each group were arranged in sub-groups of four and separate $\bar{X}$ and R limits were calculated for each group. Most of the groups were in pretty good control on this basis although the average rating and spread of limits differed widely from group to group. The control charts for one particularly well controlled group, Group N, are shown in Fig. 2.

When it comes to choosing a standard basis for comparing ratings from all groups a little problem arises. What is a proper average level and what width of limits indicates a satisfactory rating job? It happened that the average for Group N, 719, was closest to the grand average score for all groups, 715. Furthermore, this group was an old, stable group with an experienced and very capable administrator as group leader. Also the limits, although narrowest of all the groups, represented a fair spread of scores and seemed to afford a good basis for distinguishing exceptionally good or exceptionally poor performance. The failure of an average or range to stay within these limits would imply that something unusual had affected the rating and that it should be investigated. If the cause could be traced back to an individual rating, it might indicate on one hand the presence of an individual doing unsatisfactory work or on the other someone having superior accomplishments who is ready for promotion to a supervisory position. Action for training or better placement, or separation might be indicated. If evidence of some kind of bias on the part of the raters is indicated, the ratings of the suspected group would have to be examined in detail. Re-rating or rating by a different rater might be done.

When averages and ranges of all laboratory groups were plotted with limits based on the group N computations, a number of interesting results were observed. Although some of the groups were in statistical control, others showed lack of control on the average or on the range chart. Although the earlier examination of charts for single groups indicated that only a few individual ratings might be out of line, the condition of the combined charts indicated that differences between the raters was a major source of concern. As an example, the ratings by the leaders of Groups P, S, and T are compared in Fig. 3 with the ratings by the leader of Group N. For Groups P and S the range chart is in control but the average chart shows a shift to the high side for Group P and shift to the low side for Group S. Presumably the leader of Group P has been too generous and the leader of Group S too harsh in their ratings. Both need further training and practice in the use of the rating procedure. For Group T, however, the average rating is very close to the overall average and the sub-group averages are well controlled. The range chart is out of control. This indicates either a wide spread of abilities within his group or a tendency to rate some few individuals too severely and others too leniently. This rater also,

(Continued on page 42)

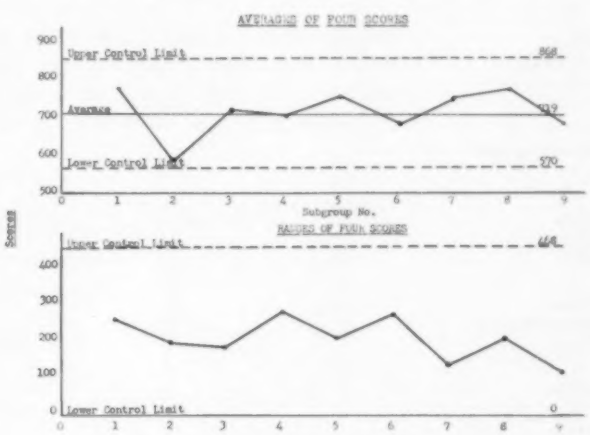

Figure 2—Control Charts for Group N Merit Ratings

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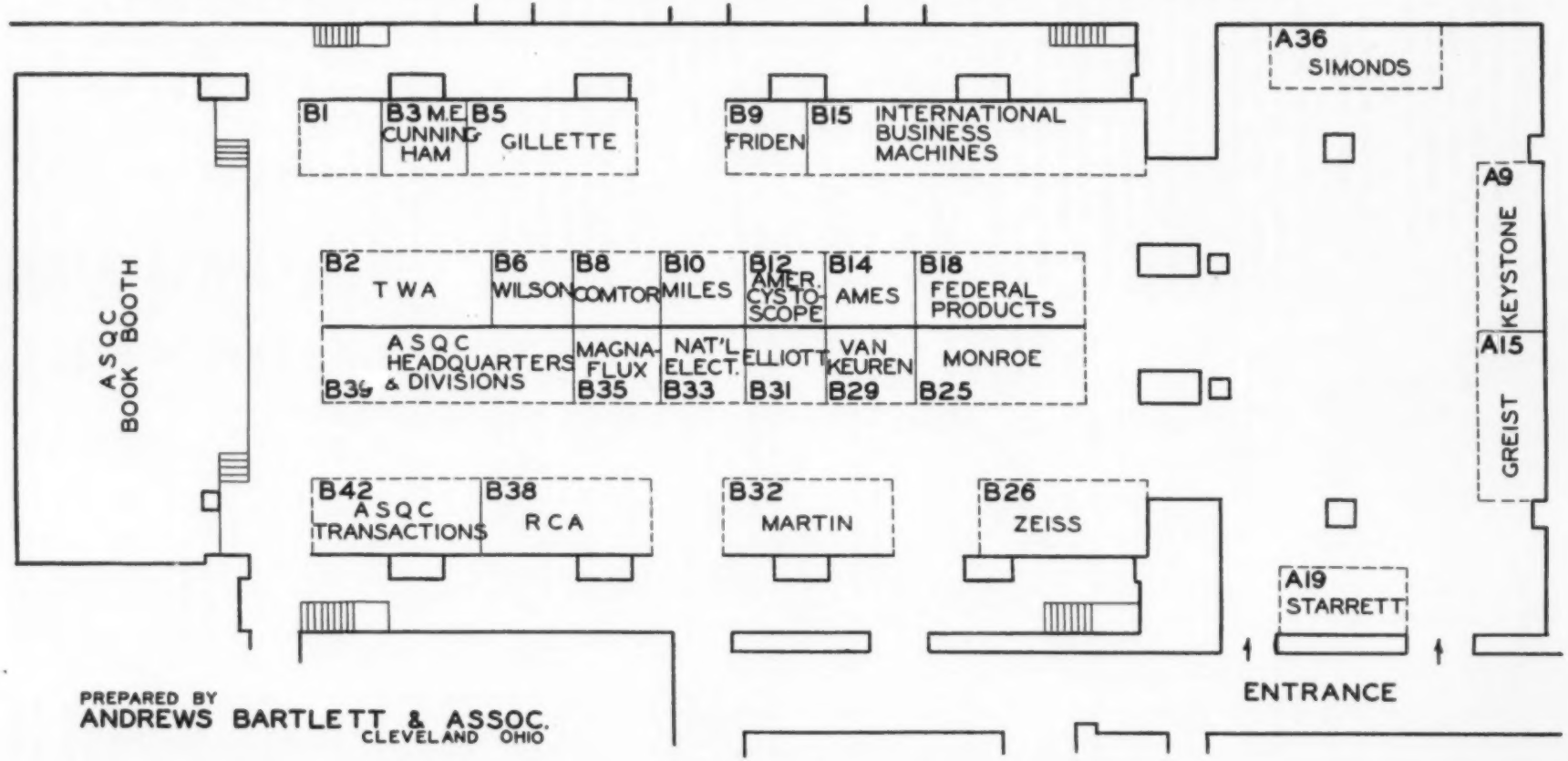

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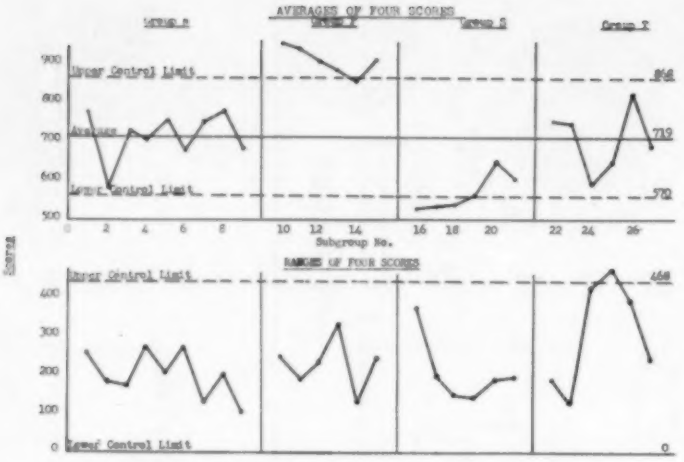

Figure 3—Control Charts for Comparison of Group Merit Ratings

(Continued from page 39)

should be called in for review of his rating technique.

One should possibly go slow in applying results of a control chart analysis of this sort without reservations. However, as a supplement to the routine methods for review of merit ratings, this kind of analysis should prove very valuable in many instances.

Comparison of Two Techniques for Rating

Another slant on the use of quality control principles in connection with merit ratings is provided by the comparison of two entirely different rating techniques applied to the same group of individuals.

A number of production and inspection personnel were rated by their supervisors on four performance characteristics: quality of work, volume of work, consistency, and initiative.

The same individuals were also rated by the personnel department by the system known as "Activity Vector Analysis." It was desired to determine whether the two systems would result in grouping the individuals in the same way as superior, average, or below average.

Control charts were used to separate the individuals who stood out as worse or better than the population norm using each of the rating systems. The following general comments could be made on the results.

(1) A.V.A. ratings were, on the average, higher than foreman ratings, i.e., more critical. This was probably to be expected.

(2) In foreman ratings, several individuals stood out as better, or worse, than the population norm. A.V.A. ratings were considerably more homogeneous, as was shown by no points outside control limits.

(3) "Quality of work" — A.V.A. ratings were distinctly less favorable than foreman ratings.

(4) "Volume of work"—the main difference was in the distribution between "average" and "below average" scores; "very high" and "above average" scores were virtually identical.

(5) "Consistency"—A.V.A. was again markedly more critical than the foremen. Perhaps the meaning of this term was not fully understood; or supervisors were more tolerant and less critical of people with whom they have constant day-to-day contact than the personnel department was.

(6) "Initiative" — A.V.A. rated both better and worse than the foremen; this trait probably was not well recognized.

An Application to Analysis of Indirect Expense

Comparison of one period or one operating unit with another is the essence of control chart application to administrative problems. However, in a highly diversified operation it is sometimes difficult to find a measure which will be of the same order of magnitude for all segments of the operation. For this reason, percentages or ratios are often most useful for comparison purposes.

An example is found in a study of indirect expenses in which the measures used in a control chart analysis are selling expense, experimental expense, home office, branch office and indirect mill expense, and total indirect expenses, all expressed as percent of sales. Data were available on an annual basis for six operating departments covering a period of eight years.

The experience of each department was divided into two subgroups of four years each, as shown in Table II, for the data on selling expense in percent of sales. Scanning of the table turns up the fact that there are many discrepancies which make direct comparison difficult. For example, throughout the first four year period, department S was way out of line on the high side. This was explained by the fact this was a newly organized department which was not expected to pay its way during the early years. As a matter of fact, for the first four

TABLE II—Selling Expense in Percentage of Sales

	DEPARTMENT					
Year	C	E	N	P	S	V
1	2.55	11.40	8.91	6.11	26.54	0.63
2	2.47	9.99	7.37	6.57	33.03	0.39
3	4.07	10.83	10.07	10.06	22.78	0.79
4	3.25	9.54	9.34	8.47	12.55	0.77
Subgroup Average	**3.09**	**10.44**	**8.92**	**7.80**	**23.73**	**0.65**
Subgroup Range	**1.00**	**1.86**	**2.70**	**3.95**	**20.48**	**0.40**
5	3.02	8.05	10.67	8.46	12.60	0.54
6	2.65	4.17	10.07	6.32	9.31	0.36
7	2.29	3.05	9.77	6.76	7.43	0.25
8	3.13	10.99	7.77	6.24	7.80	0.72
Subgroup Average	**2.77**	**6.56**	**9.57**	**6.95**	**9.29**	**0.47**
Subgroup Range	**0.84**	**7.94**	**2.90**	**2.22**	**5.17**	**0.47**

years, total indirect expenses amounted to 50 percent of sales, although by the fourth year almost all classes of expense were almost down to normal. Since there was no doubt that this department was "out of control" during this period, that set of data was omitted from the control chart calculations. A question is raised also about Department V, which was always very low. There is an explanation for this, the fact that the department makes relatively few bulk products most of which are used by the other operating departments. Likewise, Department C is obviously different. Actually, it is an old department selling a small number of products to well established markets. Although such results may be desired as the ultimate goal of all departments, it did not seem reasonable to include them in determining limits in the current comparison.

Seven subgroups were used, therefore, to calculate limits for a chart of individual measurements, as follows:

Individual limits: $\overline{X} \pm E_2\overline{R}$
$= 8.50 \pm 1.457 \times 3.82$
$= 8.50 \pm 5.57$
$= 14.07$ and 2.93

Range limits: $D_4\overline{R}$ and $D_3\overline{R}$
$= 2.282 \times 3.82$ and 0
$= 8.72$ and 0

The resulting control charts are shown in Fig. 4. Department C was out of control on the low side, as was to be expected. Department E while in control, was above the average during the first period and below average for most of the second. This department was most affected by military demands and the high results were certainly due to lack of military demand in those years. Department N was always above the average. This department was selling in a highly competitive market and had, except for the new department, S, the highest average selling expense for the whole eight years. This is not a desirable situation but may be an unavoidable one. It was noted that the experimental expenses of this department were also high. For Department P, the overall control is very good. Department S was out of control on the high side during the early years. Department V was, as noted, always out of control on the low side.

A similar analysis was made for the three other measurements studied with much the same results.

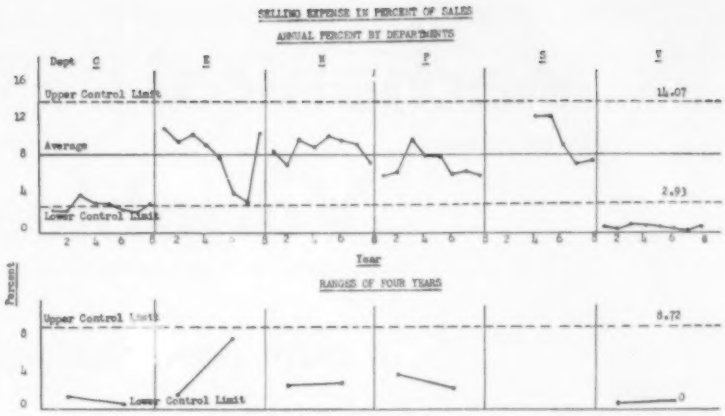

Figure 4—Control Charts for Analysis of Selling Expense

The generally satisfactory experiences of Departments C and P are shown at a glance. The temporary difficulties of Department S are very apparent while the unusual experience of Department V stands out. The peculiar dependence of Department E on military purchasing is clearly marked. The similarity between the competitive situations of Departments N and S is particularly clear due to the similarity of results in the last four year period.

It is believed that this kind of an analysis is helpful to general management in comparing and understanding operations. Furthermore, this kind of information can be of use to the individual operating departments by leading them to action to keep their results in line.

Conclusion

Stated in general terms, the use of statistical and graphic techniques provides *a method for reaching decisions and directing action to control costs.* The further down the managerial ladder we go, the less organization we find for *decision, action and cost control.* We pay well for administrative ability and for the statistical information on which administrative decisions are founded. Through a quality control program, the same advantages are obtained down to the lowest supervisory level on a self-paying basis. A highly respected administrative tool is extended in its scope and usefulness. Because it represents an extension of an essentially managerial function, it should be directed from a policy-making level. Since very often in industry administrators arise from the ranks, the extension of the appreciation of the value in statistics will provide a means of training for administrative responsibilities.

References

(1) Bicking, C. A. and Lorber, S. J., "Management Uses of Statistics," *Steel Processing, 40,* 2: 108-10, Feb. 1954

(2) Bicking, C. A., "The Application of Quality Control to Administrative Problems," *Industrial Quality Control,* Vol. VI, No. 6, May 1950, p. 21-25

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A Mechanical Variables Sampler

JOSEPH ALBERT GREENWOOD

*Headquarters, U. S. Air Force, Washington, D. C.**

This article describes a simple device with which one can perform variables acceptance sampling with practically no calculations and yet with good precision. It is based on the theoretical results of references[1,2] which are also the basis for the new military variables sampling standard, MIL-STD-414.

By variables sampling is meant the procedure of taking a random sample from a lot, measuring some prescribed characteristic of each member of the sample and computing the sample mean and standard deviation or average range.† Using these two calculated values in some fashion or other, a decision is made as to whether the percent defective in the lot is small enough to be acceptable. If so, the lot is accepted, otherwise it is rejected.

Without further ado we will examine a photograph of the device and show how it works by carrying through an example. It is assumed that the reader is acquainted with the general terminology of MIL-STD-105A, "Sampling Procedures and Tables for Inspection by Attributes," which terminology and definitions have been rather faithfully carried over into MIL-STD-414.

Figure 1 shows a series of curves for two-sided specification requirements and lines for one-sided specification requirements, corresponding to various AQL's (acceptable quality levels) and sample size letter I. The horizontal axis corresponds to $\bar{X}$ and the vertical axis to s. Let U, L be the respective upper and lower tolerance or specification limits. The procedure is just about as simple as plotting the point whose coordinates are $(\bar{X}-L, s)$ and accepting the lot if the point lies under the proper AQL curve (or line as the case may be). If one does not care to calculate s; then one finds $\bar{R}$ and reads off the s associated with it from the double scale at the upper part of Fig. 1, and then plots the point $(\bar{X}-L, s)$. Note that there are no numbers on either axis, and so with no scale one could not as yet plot $(\bar{X}-L, s)$. However, that is where the indicator arm with its seven linear scales shown in Fig. 1 becomes useful—to permit one set of curves to solve all such problems regardless of the units in which they are expressed. Now we will carry through the example.

*This article was prepared while Mr. Greenwood was with BUAer, Navy Department.

†Sample mean $= \bar{X} = (X_1 + X_2 + \ldots + X_n)/n$

Sample standard deviation $= s = \left[\sum_{i=1}^{n} (X_i - \bar{X})^2/(n-1)\right]^{1/2}$

Average range $= \bar{R}$ may be found when the sample is a multiple of five. The range (largest value minus the smallest) is found for each group of five readings taken in their natural order and the average of the ranges is $\bar{R}$. When the sample size is less than ten, the range of the sample is used.

Two-Sided Specification Limits

The nominal diameter and tolerance on certain bolts are given by 0.5000 ± 0.0300 inches, or from $L = 0.4700$ to $U = 0.5300$ inches. A lot of 1200 bolts is received and the Inspector takes a random sample of 30 bolts to apply an AQL of 2.5 percent defective using average range. (This situation corresponds to the sample size letter I as indicated in Fig. 1.) The sample measurements are given in Table I.

$$\bar{R} = (0.0213 + \ldots + 0.0190)/6 = 0.02312$$

From the double scale at the top of Fig. 1,

$$s = 0.0098.$$

$$\bar{X} = (0.5150 + \ldots + 0.5068)/30 = 0.51105.$$

$$U - L = 0.0600$$

$$\bar{X} - L = 0.04105$$

We have now finished the calculations, and the rest of the operation consists of taking three steps with the scale arm and its two indicators, as shown successively in Figures 1, 2 and 3.

In Fig. 1 the scale arm is horizontal. Call the left and right hand indicators (a) and (b), respectively. Set indicator (b) on $U - L = 0.0600$ on one of the seven linear scales on the scale arm, but in the region to the right of the large basic square. Only one such possible point exists in general. Indicator (b) is set thus in Fig. 1 and once set will not be moved from its position on the scale arm.

Rotate the scale arm to the position shown in Fig. 2 wherein the lower point of indicator (b) coincides with the vertical edge of square. Now move indicator (a) to $\bar{X} - L = 0.04105$ on the same one of the seven

TABLE I—Diameters of 30 Bolts

0.5150	0.5033	0.5094
0.5040	0.5048	0.5099
0.5253	0.5124	0.5008
0.5177	0.5072	0.5286
0.5181	0.4989	0.5106
R = 0.0213	R = 0.0135	R = 0.0278
0.5314	0.5043	0.5138
0.4961	0.5198	0.5078
0.5135	0.4980	0.5174
0.5154	0.5149	0.4984
0.5181	0.5094	0.5068
R = 0.0353	R = 0.0218	R = 0.0190

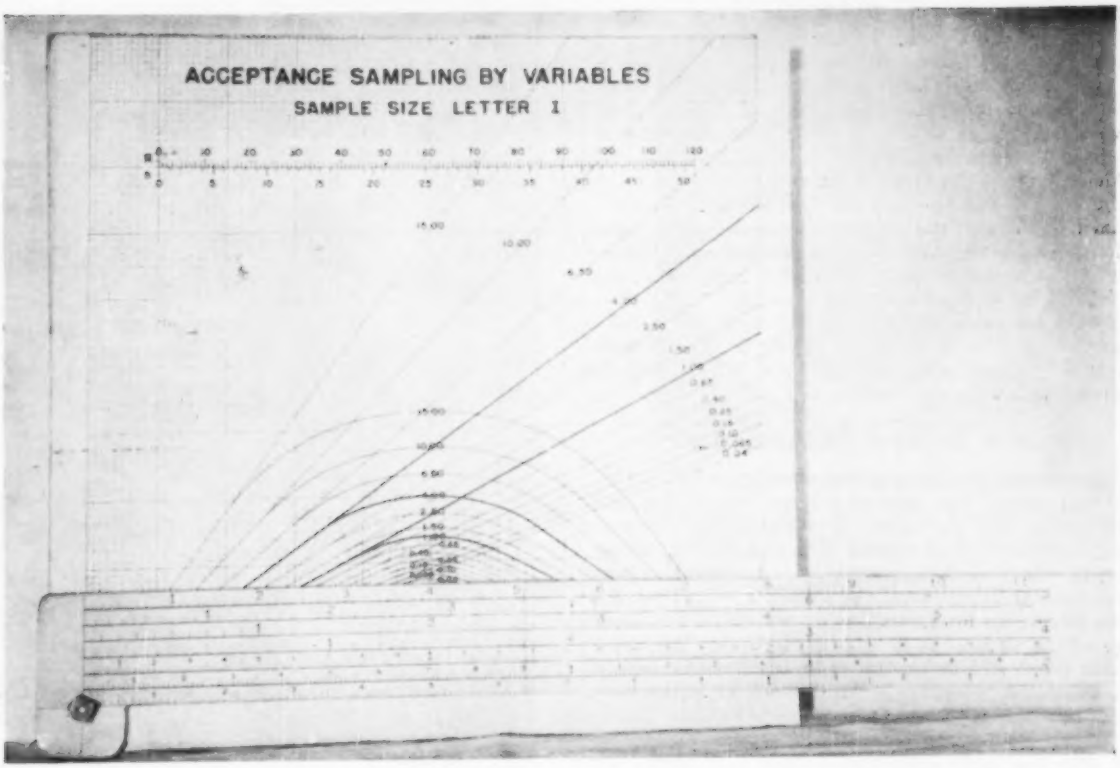

Figure 1

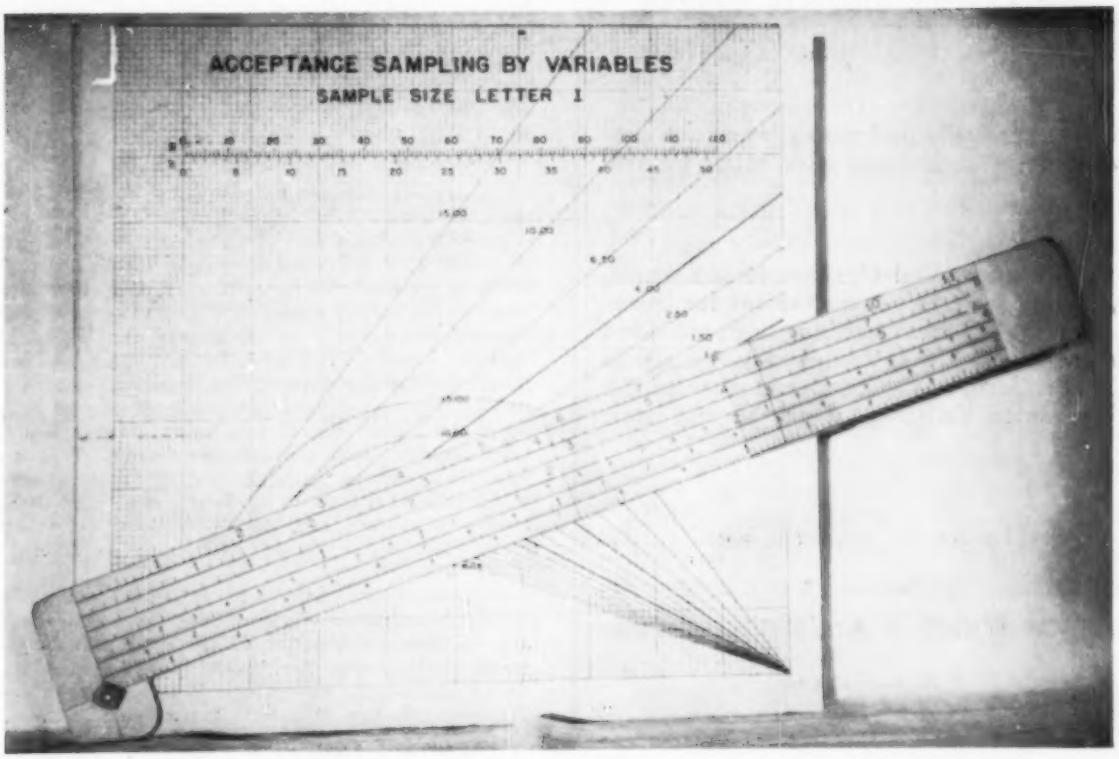

Figure 2

scales containing U − L. This is done in Fig. 2. Make a dot at the lower point of indicator (a).

Again rotate the scale arm to the position shown in Fig. 3 wherein the lower point of indicator (b) coincides with the upper horizontal edge of square. Now move indicator (a) to s = 0.0098 on the same one of the seven scales containing U − L. This is done in Fig. 3. Make a dot at the lower point of indicator (a).

The vertical line through the first dot and the horizontal line through the second dot intersect in a point which is under the AQL = 2.5 percent curve. Therefore the lot would be accepted. Had it been above the curve, the lot would have been rejected.

In brief summary, the three operations are: Set indicator (b) on U − L as shown in Fig. 1; set indicator (a) at $\bar{X}$ − L with scale arm as in Fig. 2; and set indicator (a) at s with scale arm as in Fig. 3.

Single or One-Sided Specification Limit

Suppose only the lower specification limit, L = 0.4700, had been given, but otherwise same sample size and same AQL. The procedure is a bit simpler, if anything. As before, one obtains $\bar{X}$, s and $\bar{X}$ − L. However, in this procedure, replace U − L (which is now non-existent) by the larger of s and $\bar{X}$ − L. Then if s is the larger, the intersection point will lie on the upper edge of the square. If $\bar{X}$ − L is the larger, the intersection point will lie on the right edge of the square. Otherwise the procedure is carried out as in the two-sided case but using the AQL *line*.

If only the upper specification limit U is given, one obtains $\bar{X}$, s and U − $\bar{X}$. Then replace $\bar{X}$ − L by U − $\bar{X}$ in the above procedure, following the same instructions word for word.

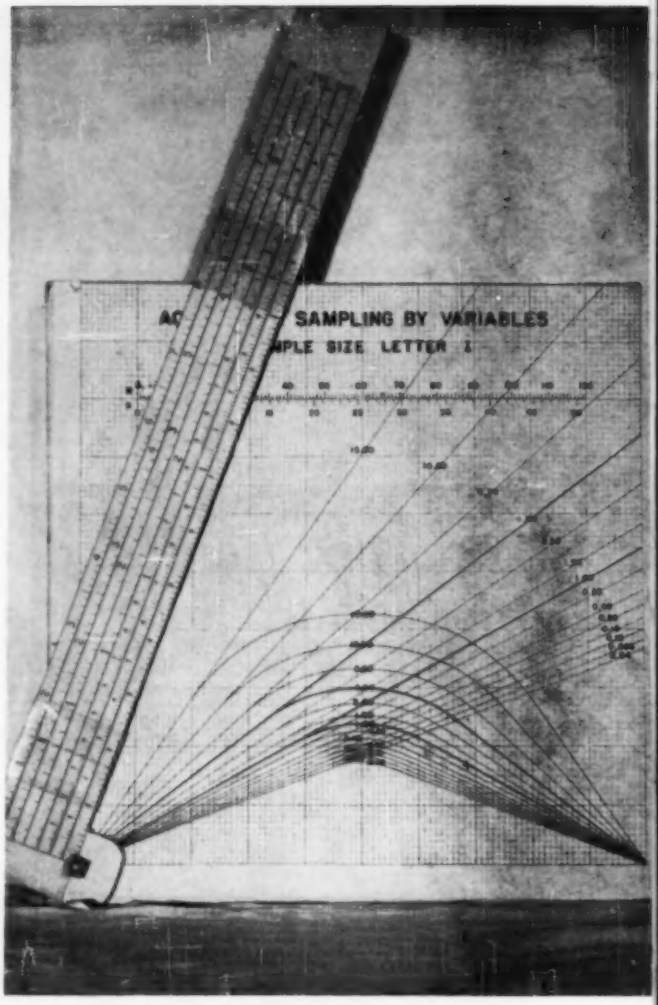

Figure 3

According to the theory of the references [1, 2] the pairs of values $\bar{X}$, s which correspond to acceptance of the lot form a closed region, which may be plotted as was done in the curves shown in Fig. 1. The curves correspond strictly to s as calculated from the sum of squares formula. However, by spot-checking points it appears that the same curves may be used for the $\bar{R}$ method (as was done in the example above) except when the sample size is, say, below seven and at the same time the AQL is below one percent. This is not much of a practical restriction and so it does not appear worthwhile at present to produce a special set of $\bar{X}$, $\bar{R}$ curves, which could be done. We point out that the known standard deviation case is not considered in this article.

As pointed out earlier, this variables sampling calculator is intimately related to the new military standard, on variables sampling, MIL-STD-414, in that it is based on the same theory, and has the same set of AQL's and sample size letters. It will accept or reject the same lots that MIL-STD-414 will, and because of this may be considered as a simple way to carry out one of the major functions of MIL-STD-414. The accuracy is quite adequate since, in order to make the

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points fall on a smooth-appearing curve, accuracy as good as that of the tables in MIL-STD-414 was required. While the chart containing the AQL curves of sample size letter I, only, is shown in Fig. 1, a similar chart has been prepared for each of the sample size letters from A to Q*.

If the following information (which is equivalent to similar information and instructions found in MIL-STD-414) were, say, printed on the reverse side of the device or otherwise easily available, the calculator would become practically self-contained. Note that a larger sample size is generally required if one uses the $\bar{R}$ method rather than calculating the s from its definition.

Sample Size Code letter	Sample Size for $\bar{R}$	Sample Size for s
B	3	3
C	4	4
D	5	5
E	7	7
F	10	10
G	15	15
H	25	20
I	30	25
J	35	30
K	40	35
L	50	40
M	60	50
N	85	75
O	115	100
P	175	150
Q	230	200

Tightened Inspection: Use same sample size letter as would be involved in normal inspection but next smaller AQL. For example when going to tightened inspection from normal inspection with sample size letter G and AQL 4.00, one would use the chart with sample size letter G and AQL 2.50.

Reduced Inspection: Use the sample size letter in the following table associated with the proper sample size letter of normal inspection. Also use the next larger AQL than given for normal inspection. For example, suppose normal inspection has sample size letter G and AQL 1.50. To apply reduced inspection, use the chart of sample size letter D and AQL 2.50

Normal	B C D E F G H I J K L M N O P Q
Reduced	B B B B C D E F F G H H I J M N

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(1) Resnikoff, George J., "A New Two-Sided Acceptance Region for Sampling by Variables," *Technical Report No. 8*, Nov. 14, 1952, Applied Mathematics and Statistics Laboratory, Stanford University, Stanford, Calif.

(2) *Technical Memorandum*, "MIL-STD-414", Bureau of Ordnance, Navy Department, August 1957

(3) *MIL-STD-414*, Sampling Procedures and Tables for Inspection by Variables for Percent Defective"; Supt. of Documents, U.S. Govt. Printing Office, Washington, D.C.

*The author is indebted to Miss Fern Stenwick for the calculations and preparation of the charts.

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There is dramatic evidence today of the far flung role of science in man's conquest of his environment. While science compresses the infinite reaches of outer space, it also seeks control of the tiny virus.

Thus, the thirst for knowledge – the arena of pure research – may send us in many directions. No matter what the immediate goal may be, however, the ultimate aim is a better life for everyone.

In the past, man has invariably been the beneficiary of an era of great scientific development. The hope is universal that he will benefit in the future.

MSD **MERCK SHARP & DOHME**
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From the Scrap Box

MASON E. WESCOTT, *Editor*

University College, Rutgers University, New Brunswick, N. J.

Other Staff Groups

Can Use Statistics Too!

S. REED CALHOUN and PAUL E. GREEN

Lukens Steel Company, Coatesville, Pa.

Few are the quality control engineers who have not at some time met the proverbial blank wall (or at least the blank look) when it came time to communicate the findings of some statistical investigation to the consumer of those findings. Invention of non-technical synonyms for terms such as standard deviation, correlation coefficient, and the like have probably taxed the semantic resources of most of us at one time or another. Not infrequently, this attempt at translation may create the impression the statistician is talking down to his hearer, a situation not likely to promote the best of interpersonal relations. A hurried, informal explanation of the underlying concepts of probability and statistical decision theory cannot usually be relied upon to provide a functional grasp of these ideas through which meaningful communication can take place.

Contributing to a dilemma in this respect are the important contributions which statistical methodology has made in recent years to other industrial staff activities usually considered outside the domain of quality control, e.g., industrial engineering, auditing, experimental research, market research, and design engineering to name a few. The industrial statistician, whether he be engaged in the substantive area of the control of quality or design of a market survey, nevertheless possesses a kit-bag of techniques which can be frequently employed in the solution of problems seemingly foreign to his usual area of interest.

At Lukens Steel Company, some progress has been made toward the resolution of the above mentioned dilemma through the design and conduct of formal training courses in applied statistics. The characteristics of these courses and the lessons we have learned from them are the subject of this article. The fact that these seminars in our own instance were conducted by operations research personnel is the result of a particular set of circumstances rather than being germane to the idea.

Our efforts to date have been principally with two groups; the Industrial Engineering, and the Research (Metallurgical) Divisions. Three formal courses have been given and various supplementary teaching aids have been prepared to (1) keep the material presented in the courses current, and (2) serve as a memory jog for the student.

Industrial Engineering Division Courses

In looking around for the material most pertinent to industrial engineering applications, our attention was focused upon two major areas:

(1) Regression and correlation analysis

(2) Work sampling

The character of our business, being largely job shop, is that work standards and, ultimately, incentive plans, are usually based on some variable characteristic(s) of the product, e.g., weight, area, gage, etc. Herein lay a "natural" for regression and correlation analysis. Although our Industrial Engineering personnel had generally used scatter diagrams and eye estimates of the functional relationships of time study results with product variables, recent interest had settled on the possibility of employing mathematical aids, principally least squares, in data analysis.

Accordingly, a practical "want", in marketing terminology, existed which could be filled by a short course in regression and correlation analysis. It appeared the course could be made meaningful to the Industrial Engineering people by building the work of the course around statistical treatment of data familiar to them, and obtaining from the data those measures which the Industrial Engineering staff needed in their work. Further, in addition to the mechanics of curve fitting, opportunity existed for relating regression analysis to statistical estimation theory and the assumptions underlying it. The background of the attendees was such that an introductory session on the basic concepts of statistical methodology also appeared worth-while.

Actually, a set of close to ideal conditions existed. The attendance was to be small (approximately a dozen people), the group would be relatively homogenous in their knowledge of the subject material (virtually nil), and a definite application existed in their everyday work for the proposed course content. To further ease any pain, permission was granted to conduct the course on company time (one hour per week for four consecutive weeks).

Outlines of each hour's presentation were prepared in advance and distributed to the attendees. Broadly

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condensed, the material of the course comprised the following:

1. Session One—Need for statistical techniques; description vs. analytical; systematic and experimental error; errors of the first and second kind; operating characteristic curves.
2. Session Two—Two variable linear regression; least squares calculation of regression and correlation coefficients; interpretation of these coefficients; dangers of extrapolation.
3. Session Three—Multiple linear regression; relationship to the two variable case; net coefficients; build-up through simple correlation coefficients.
4. Session Four—Non-linear correlation and linear transformations; confidence interval for regression line and its relationship to estimation theory.

As you have probably already surmised, our first effort in this direction was overzealous—we included too much material. Fortunately, the level of maturity of the attendees was high enough to absorb the substance of the overly ambitious offerings, but you can imagine the results of an attempt to cover in one hour a topic such as the implications and philosophy of statistical decision theory. As it worked out, we did cover fairly successfully the main points of regression and correlation analysis, although many of the more sophisticated details could only be glossed over within the limitations of time.

A while later, we embarked on another educational venture, this time in work sampling. Some early efforts on the part of our Industrial Engineering personnel had whetted their appetites on the contribution which work sampling could make to their standards work. Inasmuch as work sampling concepts were based on the binomial distribution, this area represented an application of statistical estimation theory and random sampling techniques. The attendees were to be the same group which comprised the first session. Drawing on prior experience, we decided to cover less ground more thoroughly. Accordingly the subject matter, broadly condensed, included the following:

1. Session One—Review of first session of previous course, main emphasis being on errors of the first and second kind.
2. Session Two—Estimation theory; random sampling distributions; standard error of a proportion; construction and interpretation of a confidence interval.
3. Session Three—Work sampling demonstration; use of random number table; general layout of a work sampling investigation.
4. Session Four—Statistical independence; stratification in work sampling; review of important concepts.

A general cutting down of material enabled a more leisurely pace to be taken in the conduct of this course compared to our initial effort. Additionally, advisory assistance was rendered in several work sampling investigations which were started after the course was completed.

Research Division Course

In our Metallurgical Research Division, we had received enough requests for data analysis to suggest the potential usefulness of statistical techniques not only in making inferences from data already collected, but, more importantly, in the actual design of the experimental investigations.

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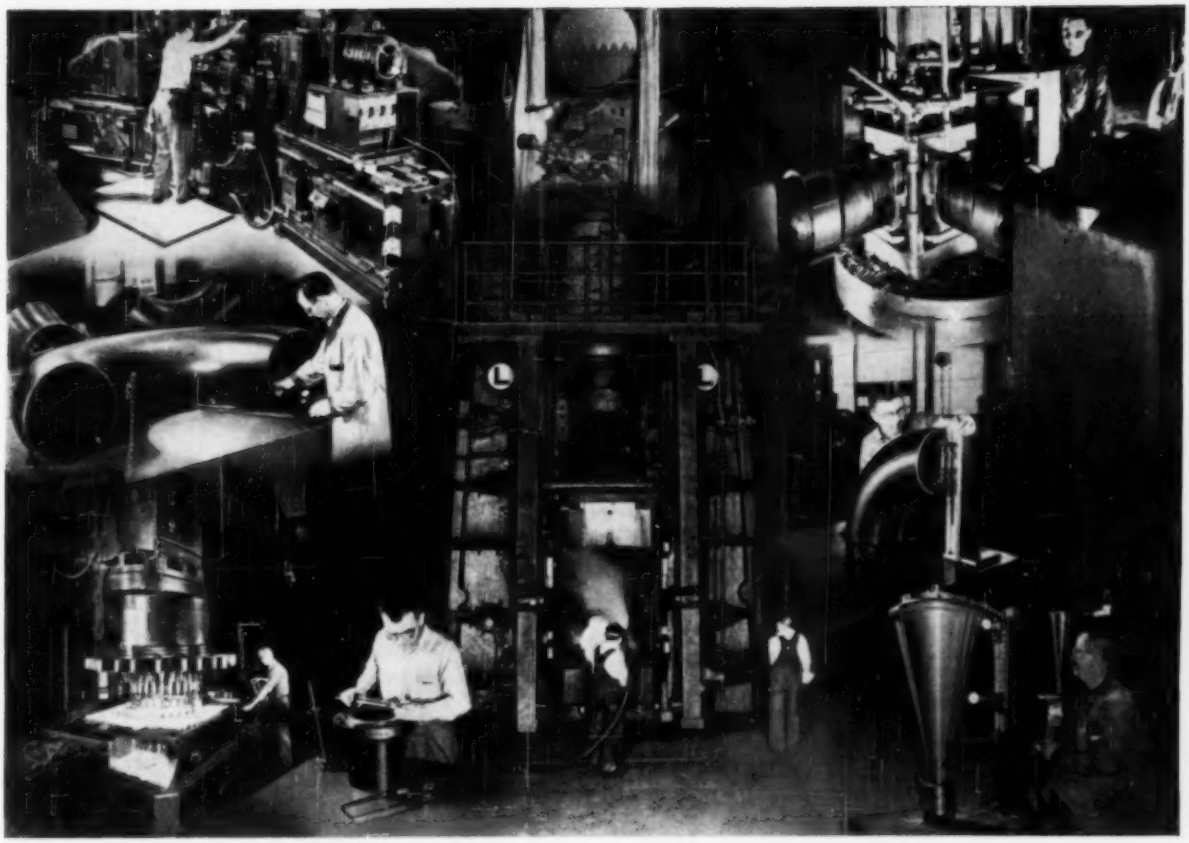

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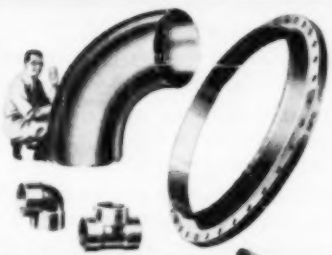

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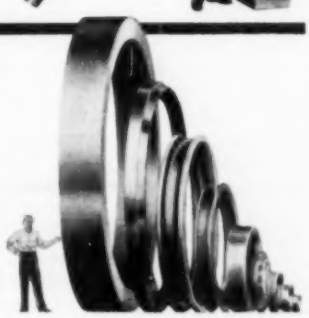

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Illustrated above are typical manufacturing and inspection operations made more effective by the application of statistical quality control methods.

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Recognizing this potential, we had prepared and distributed to our research personnel a little manual of statistical tests for small samples. The usual tests for means, proportions, variances, etc., were included as well as some elementary background material in the logic of statistical precedures. As simple in scope as the manual was designed to be, this material required personal instruction. What was envisioned at this point was a short course on design and analysis of experiments. Here again, the attendees were a mature group of individuals whose training was in metallurgy. Their better than average mathematical background permitted a rather rapid coverage of material in the eight hourly sessions. Following our earlier format, outlines were prepared covering the following subject matter:

1. Session One—Statistical foundations in experimentation; randomization; hypothesis testing and errors of the first and second kind.
2. Session Two—Probability theory; random sampling distributions; measures of dispersion.
3. Session Three—Tests for means; test for two variances; Bartlett's test; one-sided vs. two-sided tests.
4. Session Four—Regression and correlation; simple correlation; multiple correlation; orthogonal polynomial coefficients.
5. Session Five—Estimation theory; point estimation; construction and interpretation of confidence intervals.
6. Session Six—Analysis of variance; assumptions underlying ANOVA; transformations; use of F ratio; principal design types.
7. Session Seven—Completely randomized designs; significant gap and straggler tests.
8. Session Eight—Randomized block and factorial experiments; separation of interactions; use of orthogonal polynomial coefficients.

The scope of the material strongly suggested the use of rather detailed numerical examples in order for the attendees to get a "feel" of actually working through an ANOVA problem. Calculational short-cuts were explained and also demonstrated in the numerical examples. Obviously, in a survey type of course such as this, the prime objective was to stimulate a certain amount of enthusiasm and interest rather than to make accomplished statisticians of the research personnel. Inasmuch as the services of a statistical group were readily available, an added goal was to lighten the communication burden betwen the experimenter and the statistical analyst. Just as important, of course, was stressing the need for statistical services prior to conducting the experimental program.

Summary

A few generalizations can be made as a result of our still early entry into the teaching domain. Although most of these observations are self-evident, a little repetition may not be amiss. On-the-job training courses appear to fare best when:

1. Background and job interests of attendees are relatively homogenous.
2. Presentation of the material is problem oriented in terms of immediate or near-term applications.
3. The teaching group stands ready for specialized follow-up when the attendees attempt to tackle some problems on their own.
4. Supplementary teaching aids in the form of problem sheets, outlines, etc., are prepared to keep the lecture material fresh in the student's mind.
5. A need exists for the course. As obvious as this point is, our experience has shown that courses can get far afield (and, incidentally, superfluous) if the instructor dwells upon material more interesting to him than to the students.

For the instructor in the statistics orientation courses some real values seem to accrue.

1. Conducting the sessions represent a broadened scope of activity and wider intra-plant contacts.
2. The development of some familiarity by the attendees with statistical jargon simplifies the problem of communication in the day to day association.
3. Not only do the attendees benefit from the instruction; the instructor also benefits through acquiring a better grasp of the problems handled by the particular groups with whom he works.

What's New?

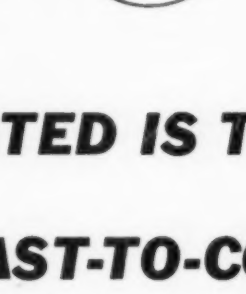
ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL

William J. Hacker & Co., 82 Beaver Street, New York 5, N. Y., the American Representative of ZWICK of Western Germany, is importing a new completely automatic electronic tensile testing machine. Especially suitable for testing synthetic fibres, threads, etc., the machine has a measuring range extending from 50 to 20,000 grams. The load measurement works with little inertia. Load and elongation are indicated, recorded and statistically evaluated automatically. Special grips eliminate pinching and the machine also provides for initial adjustment and measurement of the tension of threads.

★ ★ ★

The Sterling T818 System Test Turntable is a massive, ultra-precise, tiltable, earth axis turntable suitable for mounting complete navigation system platforms (up to 500 lbs. weight) to check the alignment of their inertial components and to observe the gyro and platform drift characteristics. The table is tiltable ($\pm 90°$), with inbuilt leveling and full 360 azimuth adjustment for accurate polar axis alignment. The 36 inch diameter table top is a precise flat with tapped mounting holes. A demountable cradle with micrometer adjustments provides for mounting a 32 inch diameter, 500 lb. spherical platform. Despite its size (the rotating element weighs approximately 3,000 lbs.) the table turns precisely and smoothly on pressurized fluid bearings. Rotational and alignment accuracies of



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Seventh Annual Advanced Management Seminar

The seventh annual advanced management seminar, a six-week course in executive development, will be held at the University of Washington, Seattle, from June 15 to July 25.

The program is designed for men already carrying substantial executive responsibility and ultimately in line for more. All courses are presented from the point of view of top management, in a training environment not normally possible in company programs or regular university courses. The seminar will prepare promising maturing executives for greater responsibility and enable them to function more effectively in their present jobs.

Opportunity to develop an integrated approach to major policy decision-making is provided through the playing of a "top management decision game." The members of the group are divided into competing "companies" and develop business strategies by making decisions on pricing, production scheduling, inventory control, marketing expenditures, research and development programming, market information, and plant capacity. These competitive decisions are then evaluated and the resultant profits or losses reported to each company. The "game" has been unanimously endorsed by past participants and described as challenging, interesting, and enlightening.

There are no formal or educational requirements for admission to the Seminar. Experience has shown that executives who benefit most are those who have revealed themselves as ambitious, adaptable to new situations, and receptive to new ideas.

Additional information and a descriptive brochure may be obtained from:

Prof. Jim Rosenzweig, Director
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±2 seconds of arc are attained, even under tilted conditions. Turntable drive is by synchronous motor at various multiples of true earth's rate. Provisions are made for incorporating a direct drive servo motor for closed loop operation. Unit is 50 inches in diameter, 63 inches high (from floor to table top) and weighs 7,000 lbs. For further information write **Sterling Precision Corp.**, Instrument Division, 17 Matinecock Avenue, Port Washington, L. I., New York, for the Sterling Engineering Report ER-122.

* * *

A new and easy-to-use method for checking the bond in honeycomb structures is the latest development added to the group of testing systems available from **Magnaflux Corp.**, 7300 West Lawrence Avenue, Chicago 31, Ill. The new test, known as Bondcheck, is sold in kit form at low cost and fills a gap in proving integrity for successful performance of honeycomb assemblies. The Bondcheck BC-1 Inspection Kit is used most successfully on metallic honeycomb, soldered, welded or brazed to the skin surfaces. The test procedure begins by cleaning the part surface and then spraying on a specifically formulated red fluid that is repelled by heat and tends to flow to the coolest area on a metal surface. Next, a controlled heat is applied from a high intensity infrared lamp. This heat is conducted from the surface being inspected to the honeycomb core wherever good bond exists between the core and the surface. Since the visible fluid flows to the coolest areas, it accumulates at every point of good bond, reproducing an exact pattern of the bonded area. Areas of defective bond are visible as gaps in this pattern. Deformed core materials are also readily apparent, with the inner core pattern visible in the outer

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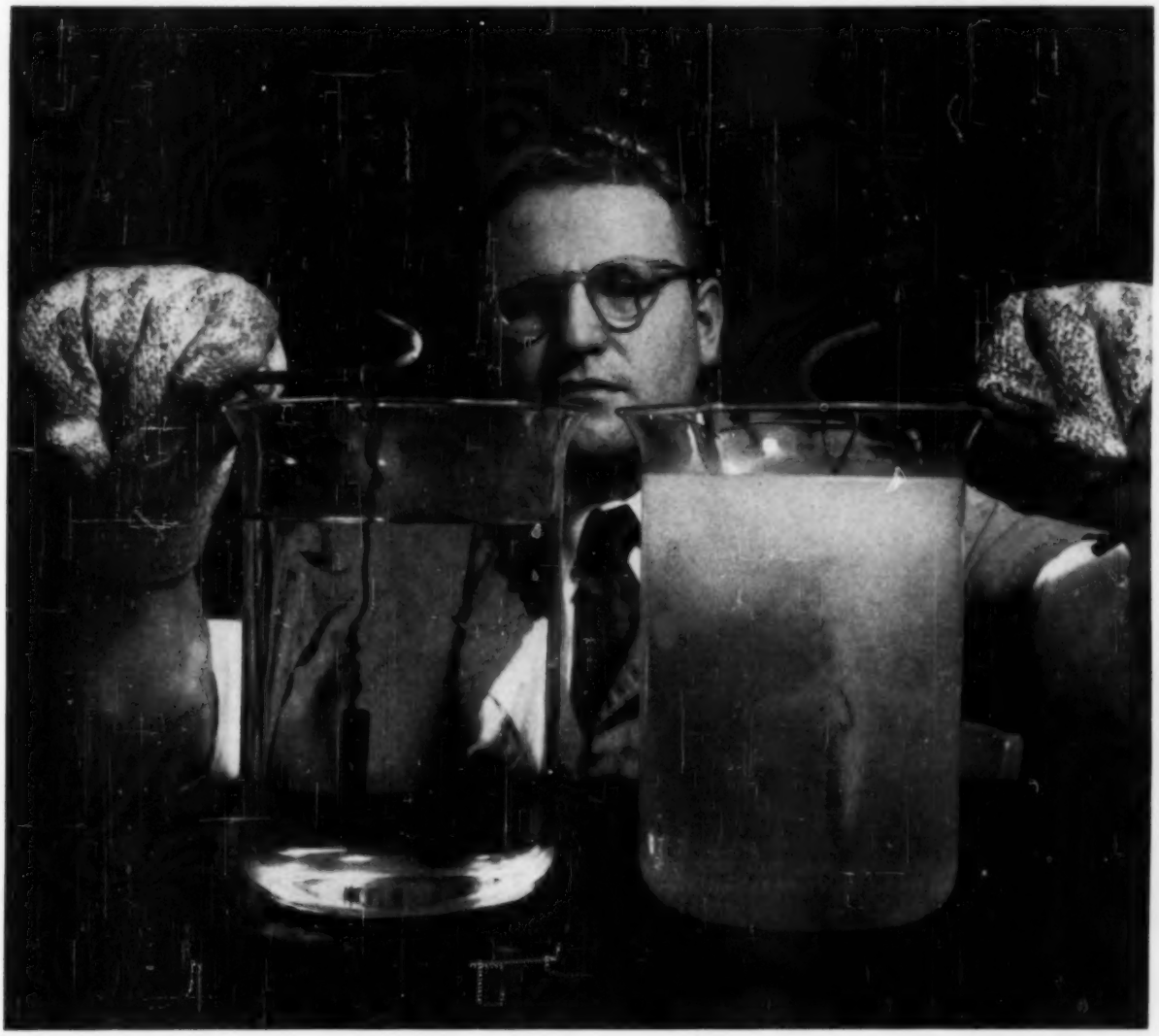
slow motion cooling... *a new way to harden steel*

red hot sample in plastic quench (right) stays in vapor stage of cooling several seconds longer than in water quench (left)



International Harvester has developed a new method of hardening steel by *plastic* quenching. This new quenching method introduces an *adjustable* cooling rate between water and oil. The benefits of adjustable plastic quenching have been demonstrated by IH metallurgists and verified by Quality Control... one more example of the importance of Quality Control and research at IH in the development of high-quality products.

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surface pattern. The test takes only a few seconds per area tested. Any complex shape can be tested, and automatic testing is practical on simple shapes. The Kit consists of two separate carrying cases. Case No. 1 contains an inspection stand, spray gun, 25 foot air hose, air pressure regulating valve, air gage and filter, one quart of bondcheck fluid, and two 12 oz. spray cans of cleaner. Case No. 2 houses the powerstat which enables the inspector to vary the heat intensity. Powerstat operates on 110 volt, 60 cycle, 1 phase current, drawing up to approximately 15 amperes.

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Lavoie Laboratories, Morganville, N. J., offers an automatic tape-programmed resistance measuring instrument which can select any two of 240 points and measure the resistance between them, in a range from 1 ohm to 9.99 megohms. In addition to selecting a 1, 5, 10, or 20 percent nominal tolerance, the Robotester may be programmed to pass any value below or above a selected median resistance. The Robotester will perform a series of circuit checks on an assembled chassis, automatically indicating a failure due to shorts or out of tolerance parts, at 60 to 100 tests per minute. The punched tape provides a convenient permanent test program and allows repetition of a production run at infrequent intervals without creating a test fixture storage or investment problem. Applications of the Robotester range from check-out of launching platforms or TV sets to operating and checking relay stacks.

★ ★ ★

A complete quality-control installation for ultrasonic thickness gaging, recording, detection of laminar flaws, including connections for automatic sorting and rejection, is now available from **Branson Instruments Inc.,** 40 Brown House Road, Stamford, Conn. Thickness of metals, glass, and plastics between 0.005 and 2.5 inches can be measured. Readings are obtained instantaneously by applying a transducer to one side of the work and reading the thickness indication on the instrument's screen and/or chart. The strip chart recorder clearly shows thickness changes which are barely visible on the screen. The recording pen is activated by an amplified signal proportional to the difference between the work thickness and some preset standard. Thus, a highly magnified profile of the surface is drawn on the moving chart. The

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gating and alarm circuit trips a realy when a part reaches predetermined dimensional limits, energizing audible or visible alarms, marking devices or sorting attachments.

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Trico Machine Products Corp., 266 Grand Avenue, Cleveland 4, Ohio have introduced the new Micro-Scale, providing a simple dimensional standard for precision setting of layout instruments. It permits setting dividers and similar tools to 3-place decimal accuracy without gauge blocks or other standards. The Micro-Scale has a direct-reading scale and a graduated dial, calibrated in 0.001-inch increments from 0 to 6, 12, 18 or 24 inches. Turning a knurled knob moves a helical scribed line on the barrel to provide the two fixed points for layout instrument settings. The Micro-Scale permits fast precision settings in the fraction of the time required by conventional tools. It is simple and easy to use, eliminating all guess work and eye strain in layout work, as well as in many applications in checking and inspection of tools, dies, and similar products.

★ ★ ★

Summer Statistical Methods in Industry Course

The third annual "Statistical Methods in Industry Course" will be held on the University of California, Los Angeles Campus during Aug. 11-22. This is a full-time program, sponsored by the Department of Engineering, University of California at Los Angeles, in cooperation with the University Extension and the Los Angeles section of the American Society for Quality Control.

To be offered are the following:

(1) A basic course in quality control by statistical methods.
(2) An advanced course in industrial statistical methods.
(3) A series of general lectures for all participants on such subjects as reliability in industry, statistics in research, quality control procedures, organizations, and reports.
(4) A "practical aids" series for all participants including computing and gaging techniques and instruments, and pertinent films.

Included in the staff will be Professor Irving Burr of Purdue University and Professor Lloyd Knowler of the State University of Iowa, and other distinguished representatives of government, education and industry.

The $250 fee includes tuition, books, supplies, ten luncheons and one dinner.

In addition to the above program, a three week course in industrial reliability will be held during Aug. 4-22. Because of previous reservations, only a limited number of registrations can be accepted for this course. Registrants should possess a degree in engineering or science or the equivalent. Fee for the industrial reliability course is $350.

For further information write Professor Edward P. Coleman, Coordinator, Statistical Methods in Industry Course, Department of Engineering, University of California, Los Angeles 24, Calif.

Research Tabulating Bureau, Dept. 440, P.O. Box 7, Indianapolis 6, Ind., has published METZGER'S TABLE OF 45,000 PER CENTS. The table is of value to researchers, statisticians, accountants, estimators, clerks, engineers, management consultants, cost departments, and others who need to make rapid calculation of percentage figures. The table contains 45,000 percents, up to 99.999 percent on the basis of 1 to 300 lines (numerator) and 1 to 300 columns (denominator). The complete table contains 54 pages, size 8½ × 11 inches. Price for the table is $4.00.

New Literature Available

A new eight-page bulletin describing complete complex motion and sine wave vibration generating systems, for use by aviation, missile and rocket design and test engineers engaged in precise vibration analysis, has been announced by MB Mfg. Co., Division of Textron Inc., P.O. Box 1825, New Haven 8, Conn.

M-S-A Particle Size Analyzer is the title of Bulletin No. 0708-1, issued by Mine Safety Appliances Co., 201 N. Braddock Avenue, Pittsburgh 8, Pa. The 4-page bulletin presents a new low-cost, general purpose instrument for determination of particle sizes in the range of 0.1 to 40 microns.

Dynametrics Corp., Northwest Industrial Park, Burlington, Mass., has just published a catalog on its line of manometers for low-cost pressure measurement. These precision instruments have been used for many years in aerodynamic and engine test work. Dynametrics Corp. also manufactures force beams for accurate measurement of forces, such as weight and torque, wind tunnel balances (strain gage and mechanical), devices for missile weight and center-of-gravity, and related data handling and read-out instrumentation.

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BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

ENGINEERED WORK MEASUREMENT, by Delmar W. Karger and Franklin H. Bayha, The Industrial Press, New York, 635 pages. Reviewed by N. L. Enrick.

This book is sub-titled: "The Principles, Data, and Techniques of Methods-Time Measurement, Modern Time and Motion Study, and Related Applications Engineering Data." History, fundamentals, applications and standards of methods-time measurement and time and motion study are covered with great clarity and detail, supplemented by a wealth of well chosen illustrative examples.

Of special interest to quality-control minded readers is the material on statistical evaluation and control-chart analysis of work measurement data, as well as the data on work-sampling or ratio-delay studies. Many helpful nomographs reduce routine statistical calculations to simple addition and averaging of individuals and ranges.

As a result, this should be a useful text, training and reference volume.

NONPARAMETRIC METHODS IN STATISTICS, by D. A. S. Fraser, John Wiley and Sons, Inc. Reviewed by R. B. Murphy, Bell Telephone Laboratories, Inc.

Professor Fraser's new book is a sophisticated approach to the problems of nonparametric statistics. Of its kind it is both excellent and unique. It begins with a review of those aspects of measure theory and its applications which in the last ten or fifteen years have come to be regarded as fundamental to scholarly treatments of the statistical problems embraced by the term "nonparametric methods." This review of measure theory sets the outlook and style for the book as a whole; it is clear that the intended audience are those who have done or are capable of doing advanced work in mathematical statistics.

The first two chapters in the book—a little less than half the material presented—are a concise theoretical treatment of basic concepts in statistics and would be most useful in teaching students suited to this approach and level of attack. The presentation avoids needless abstraction or complexity, and it is distinguished by its clarity. On the other hand, the reviewer believes that the book does not furnish all those details of measure theory, matric algebra or group theory which might be required to read the book with clear understanding if one had had no previous acquaintance with the concepts.

The man in applied statistics who seeks a handbook of techniques will not find it in this book: the emphasis is not so much on the "solutions" to nonparametric problems as on the nature of them. Indeed, specific techniques are to be found almost entirely in the Problems for Solution at the end of the chapters, and they rarely receive detailed discussion in themselves. However, much valuable material is contained in these problems and cannot be regarded as mere exercise. The reviewer feels that this treatment has been carried too far in some cases. For instance, the Wilcoxen test receives a minimum of attention, and there is no mention of the theory of runs as such nor of the Tukey-Olmstead corner-test for association. These and other tests are in themselves applications in a book which sets out to formulate concepts and prove the consequences of them on the general level. The reviewer's only criticism is that in a book pointed toward a special field in statistics this notion should not have been carried quite so far.

section briefs

ALBANY . . . On Mar. 13 Dr. Theodore Brown, Harvard Graduate School of Business Administration, addressed the section on "The use of statistical techniques in certain problems of market research." Walter A. Ruderfer, marketing research specialist of the G. E. Company of Waterford, was moderator for the problem session.

The annual June picnic committee is being selected. The time and place for the picnic will be announced at a later date.

ALBUQUERQUE . . . At the Mar. 10 meeting, Dr. Paul S. Olmstead, consulting analyst on major military projects for the Bell Telephone Laboratories, discussed the application of quality control principles to problems encountered in engineering research and development work. Especially stressed were the peculiarities inherent in R & D data.

ALLENTOWN-BETHLEHEM . . . "Stopping rules for continuous sampling" was the title of Dr. R. B. Murphy's talk given to the section at the March meeting. Dr. Murphy, quality results engineer at the Bell Telephone Laboratories, discussed procedures for calculating the critical points where inspection stops and action must be taken for several economic criteria.

After a delicious meal in Walp's Sigma Room, diplomas were given to those individuals completing the "Introduction to quality control course."

BALTIMORE . . . An excellent crowd of members and guests attended the Mar. 11 meeting which featured "Project engineering and quality control" presented by Norman C. Krause, assistant for inspection, office of quality assurance, Army Chemical Center, Edgewood, Md. An interesting picture was given by their integrated program of engineering for new projects involving the cooperative efforts of design, development, product, and QC engineers. A fine social hour with refreshments, an invaluable feature of our meetings, followed the meeting.

Officers for the 1958-59 year will be announced at the May dinner meeting.

BATTLE CREEK-KALAMAZOO . . . "Organizing an effective quality control program that pays" was the feature of the Mar. 7 meeting held at the University Center, Western Michigan University, Kalamazoo. The speaker for the evening was Harmon Bayer. A very interesting and factual speech was presented and was very well received.

BINGHAMTON . . . The May 20 meeting will include the installation of the newly elected officers for the 1958-59 season.

BUFFALO . . . "Why management should maintain or increase the quality control function in a recession" was the subject of a panel discussion held Mar. 31 at the University of Buffalo. Panel participants were V. Shelburne, R. S. Bingham, Jr., F. J. Davenport, and A. J. Kukla.

BUZZARDS BAY . . . Oscar H. Bishop, QC manager of the Foil Division of the Reynolds Metals Co., Louisville, Ky., was guest speaker at the Mar. 11 meeting. He gave an illustrated talk on "Quality control in the production of aluminum foil." Kenneth Bennet presided at the informative session. A slate of officers to be elected for the coming season was presented. They included: Hans E. Picard, Aerovox Corp., chairman; John E. Ruggles, New Bedford Textile Co., vice chairman; Mrs. Elizabeth Counsell, Cameo Curtains, Inc., secretary; and Mrs. Geraldine Habicht, U. S. Navy Central Torpedo Office in Newport, treasurer.

CHARLESTON . . . The section is very proud of its record of education in the field of SQC. Shortly after its institution

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University of Michigan

The University of Michigan has scheduled its eleventh annual ten-day intensive course in quality control by statistical methods for Aug. 18-28, on the campus in Ann Arbor. This is a first course for executives and supervisory personnel; it is practical and mathematically non-technical. It includes the standard control charts and sampling acceptance plans together with other basic techniques.

Instruction includes lectures, demonstrations, practice sessions and conferences. The staff will include Professors P. C. Clifford of Montclair State Teachers College, F. C. Leone of the Case Institute of Technology, E. G. Olds of the Carnegie Institute of Technology, and C. C. Craig of the University of Michigan. The fee will be $125.

Please address inquiries to the course director, Prof. C. C. Craig, 106 Rackham Building, Ann Arbor, Mich.

in 1957, the section sponsored a course in basic statistics which was attended by about 70 members and non-members. On Mar. 5-7 about 31 members, mostly from the section, enjoyed Dr. Stuart Hunter's instructions on the Box course, and at present there are 37 taking a basic course and 26 taking a course in statistical methods for industrial application.

CHICAGO . . . Featured at the Mar. 11 meeting of the Calumet sub-group was W. C. Tuneig of the Standard Oil Co. His topic was "Graphical statistics."

Thomas Caywood of Caywood-Schiller Associates addressed the section on Mar. 19 presenting a survey of operations research techniques. Among the approaches discussed were the queueing theory, the inventory control method, linear programming, the distribution (travelling salesman) technique, and simulation techniques.

The former Fox Valley sub-group has attained full section status under the name of the St. Charles section. To the new section, starting out under the leadership of Stephen T. White, go our best wishes for continuing growth and success.

CINCINNATI . . . At the March meeting, Arthur Bender, Jr. gave a well received talk on Kwick-C, his very graphical method of using probability paper to illustrate a distribution.

Seventy-five people were present Mar. 20 at the Lexington Signal Depot Officers Club when the chairman and treasurer of the section and the chairman of the Hamilton-Middletown section assisted Society president Leon Bass in the presentation of the charter to the Lexington section. The section also presented an inscribed gavel to the Lexington section.

At the May 21 meeting G. G. Parkin, Minnesota Mining and Mfg. Co., will speak on "Tests of significance in industrial processing."

Plans are firmed up for the June dinner dance to be held June 13 at the Greenhills Country Club. This gala affair will be a joint social meeting with the Hamilton-Middetown section. Both sections will install their newly-elected officers during the course of the evening.

COLUMBUS . . . The section will hold its annual officer's business meeting on June 11 at the Southern Hotel. Order of business for this meeting will be officer's reports, committee reports, and the 1958-59 program report.

CORNING-ELMIRA . . . The March meeting was highlighted by Cuyler J. Hawkes of Eastman Kodak who spoke on "Attribute sampling of parts from continuous production lines."

The June meeing will be some form of social get-together for members and their families. The probable date is June 14.

CUMBERLAND . . . Frank W. Kroll, Jr. of Esso Standard Oil Co. addressed the section on Mar. 6. His discussion, "Effective quality control program for the industrial control laboratory," was a description and critique of the QC program which has been successfully carried out for three years at the Bayway Refinery.

DALLAS-FORT WORTH . . . On Mar. 13 Jack Gant, QC engineer supervisor, Jet Engine Dept., General Electric Co., presented several practical applications of SQC in a true job shop (run size-1 unit).

The 3rd annual QC symposium was held at TCU on Mar. 15. The tremendous turnout of about 300 was adequate evidence the planning committee did a splendid job in procuring top notch men in the field of QC and presenting a varied and stimulating program. The prominent guest speakers included Simon Collier, David Hill, John Holland, Winthrop Spencer, James Coburn, Dan Devine, and Jack Gant (ably substituting for Leon Bass).

EVANSVILLE-OWENSBORO . . . W. C. Vissing of the Eli Lilly Co. was the speaker at the Mar. 18 dinner meeting held at the Shady Rest Restaurant, Owensboro. Mr. Vissing's subject was "Statistical methods in sorting operations."

The anual ladies night dinner will be held at the Hotel Soaper in Henderson, Ky. on May 20. The new officers will be installed at this meeting.

GREATER MUSKEGON . . . Forty-three members and guests thoroughly enjoyed a family style shrimp dinner at the Mona Lake Boating Club on Mar. 13. A panel discussion on "Quality control in industry" proved to be most interesting. The panelists were Henry Elliott of Continental Motors, Rudolph Arndt of Anaconda Copper, and William Henkel of General Electric. Al Lindberg of Brunswick-Balke acted as moderator.

Due to the type of programs on the section's agenda for April and May, the annual election of officers was held at the regular monthly meeting in March. Officers elected included: chairman Merrill S. Bailey, Anaconda Wire & Cable Co.; vice chairman Lawrence P. Long, Army Ordnance (CMC); secretary R. L. Porter, Muskegon Piston Ring Co.; and treasurer Basil B. Smith, Michigan Spring Co.

HAMILTON . . . Henry J. Becker, Society vice president, presented his paper "Quality control in the steel industry" at the Mar. 13 meeting. The large attendance of members and guests brought along many problems which were capably dealt with by Mr. Becker.

HAMILTON-MIDDLETOWN . . . Ellsworth Sims, general manager of the Estate Division of the Whirlpool Corp., presented an interesting and informative talk on "Whirlpool and QC." An excellent dinner was enjoyed by courtesy of the Whirlpool Corp.

The annual dinner dance will be held June 13 at the Greenhills Country Club. Preliminary plans indicate that the 1958 dinner dance wil be a gala affair furnishing a good time for all.

HARRISBURG . . . On Mar. 5 a Ladies Night meeting was held at the Lancaster Conestoga Country Club. J. William Frey, chairman of the German Department of Franklin & Marshall College, was the speaker. The meeting was highly successful and Dr. Frey an entertaining and very interesting speaker.

Harvey's Smorgasbord in York was the site for our Apr. 2 meeting. One of our favorite speakers was present. Dr. Ellis R. Ott spoke on the subject of "Some industrial experiments—case histories." This meeting was our annual "**bring the boss**" **night.**

HARTFORD . . . James Dolby gave a very interesting talk on market forecasting through the use of control charts. He also informed his large audience of the techniques used by different branches of his organization in informing management daily of product defect status. A lengthy discussion on statistical methods of reporting followed.

KANSAS CITY . . . The March meeting featured Dr. Paul S. Olmstead of Bell Telephone Laboratories who spoke on "Philosophical implications of SQC." Dr. Olmstead is a Fellow of the Society and has served as lecturer on engineering statistics for the Stevens Institute of Technology and has been a consultant on QC for Princeton University.

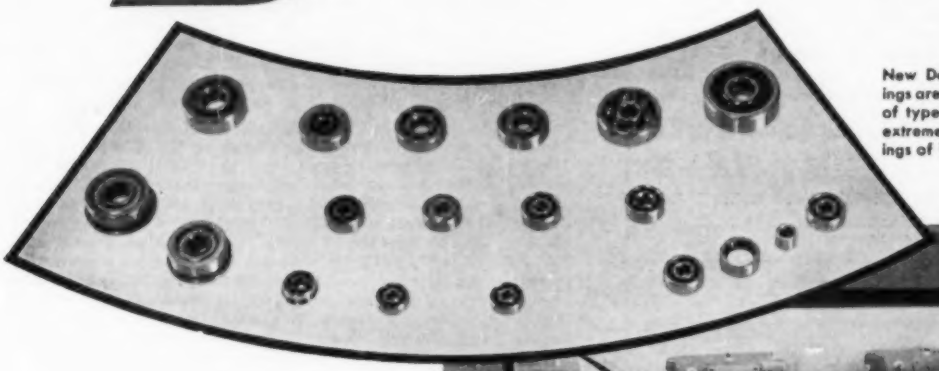
The regular 7:30 dinner was preceded by a products exhibit of the Wilco Electric Co. Various electronic communications components were displayed.

LANSDALE . . . On the night of Mar. 13 the section was honored to have Dr. Ellis Ott of Rutgers University as the last official speaker of the current season. Dr. Ott's talk concerned Indian industry and quality control on which he is an expert, having made two trips to the land of Buddha. He returned from his last trip two months ago. His last visit to India under the UN's technical assistance program was concerned with the teaching of advanced techniques of the quality control program his group established in 1954. After his talk and the showing of his slides, the section agreed that Lowell Thomas couldn't have done better.

LIMA . . . At the Mar. 12 dinner meeting, the section elected Martin Medow, quality control representative for Ford Motor Co. with the Ex-Cell-O Corp., as chairman for the 1958-59 season. Mr. Medow, along with vice chairman Stephen J. Kadar of Lima Ford Engine Plant, treasurer Clair Zimmerman of Superior Tube Co., and secretary Paul Caruso of Lima Ford Engine Plant, will be installed at the May meeting.

The guest speaker for the evening was William Barker, quality engineer of General Electric's Evendale plant in

ND FACTS



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Rochester Institute of Technology

The 15th annual Rochester Institute of Technology "Quality Control for the Chemical Industries" course will be held from June 23 to July 2. The course will offer two new features this year.

Following the daily program consisting of a series of conferences, lectures, and laboratory periods, informal evening seminars will be held which will offer an opportunity for the discussion of student's individual problems.

It is anticipated that this year's course will have one of the largest enrollments ever. In the past, over 100 national organizations have enrolled employees in the course which is devoted exclusively to the control problems of the chemical and process type industries.

For further information contact:

Robert D. Pease
Associate Director
Rochester Institute of Technology
65 Plymouth Avenue South
Rochester 8, N. Y.

Cincinnati. His topic was "Quality control . . . what does it mean to you?" Mr. Barker is chairman of the Cincinnati section.

LOS ANGELES . . . The panel discussions by Dr. Alexander Boldyreff and R. H. Anderson under the guidance of moderator Kenton R. Whilhite, enlightened "SQC techniques in the management field."

LOUISVILLE . . . At the Mar. 10 meeting held at General Electric Appliance Park, the nominating committee reported the nominees for the 1958-59 officers and nominations were accepted from the floor. A short educational capsule on "The control of variances in cigarette weights" was presented prior to the presentation "Statistical quality control applications for fabricating steel" by Guy Campbell of General Motors, Ternstedt Division. Refreshments were served following the meeting.

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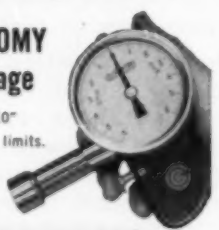

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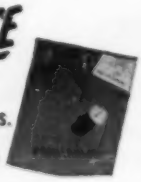

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REQUEST BULLETIN 50

MEMPHIS . . . Dr. Paul Olmstead, statistical engineering consultant with Bell Telephone Laboratories and a member of the board of directors of the Society, addressed the Mar. 21 meeting on "SQC in engineering research and development."

At the June 6 meeting John James, quality control manager of Flexonics Corp., will speak on "Classification of defects."

METROPOLITAN . . . On Mar. 25 the section held one of its most outstanding meetings of the year. The meeting was held at the United Nations Building in New York and was sponsored jointly by ASA. Dr. William R. Leonard, chief of statistical services for the UN and president of ASA, did an exceptionally good job handling arrangements at the UN.

We had 145 people attending a tour of the UN Building and 181 attending a very fine dinner in the UN Cafeteria. The "piece-de-resistance" was the meeting itself. Over 200 people, including many wives of those attending the dinner, attended the interesting discussion held by a group of distinguished QC experts. The panel consisted of Prof. Paul C. Clifford, Dr. W. Edwards Deming, Dr. Joseph M. Juran, and Dr. Ellis R. Ott, with Dr. Samuel S. Wilks as moderator; certainly an all-star cast. Each speaker talked about the applications and problems of QC in the countries they visited including Sweden, Denmark, Germany, Japan, Australia, and India. The meeting closed with very interesting slides taken by Dr. Ott while he was in India.

MID-HUDSON . . . Fifty-three members and guests were present for the March dinner meeting at the Anchor Inn in Poughkeepsie to hear Joseph T. Rowinski of IBM speak on "Vendor quality rating."

Officers for the 1958-59 season were elected. They are chairman Frank J. Sindelar, first vice chairman William M. Cranson, second vice chairman Gerald H. Overbagh, treasurer William A. Beneshan, and secretary Casper J. Rose.

The last meeting of the season will be a social evening to be held June 3 at Germania Hall, Poughkeepsie.

MILWAUKEE . . . The 5th annual all-day clinic was held at the Wisconsin Hotel on Mar. 14 and was a resounding success. Twelve sessions—devoted to a variety of subjects from brewing to foundry—were fully attended and promoted much favorable comment. W. C. Brice, works manager of International Harvester Co., gave an emphatic send off with his keynote speech on the expanding role of the QC engineer in industry. Dr. George Parkinson, vice provost of the University of Wisconsin-Milwaukee, added a serious note at the luncheon with his remarks on "Education for survival." Much credit can be given to George Craycraft, general chairman of the clinic, for a job well done.

MINNESOTA . . . The student union at the University of Minnesota was the scene of the March meeting. George L. Collier of Pratt and Whitney spoke on gaging. His talk was illustrated with a movie supplied by P & W.

MONTREAL . . . F. X. Donohue of the Nestle Co. gave a very interesting talk on "Quality control applications in the food industry."

The feature of the May meeting was Kenneth G. Cook's talk on "Vendor-vendee problems in the metal industry." Mr. Cook is with Thomas & Betts Co., Inc.

On June 4 the Reverend Father McShane will talk on "Adult education" at the annual dinner meeting to be held at the Queen's Hotel at 6 p.m.

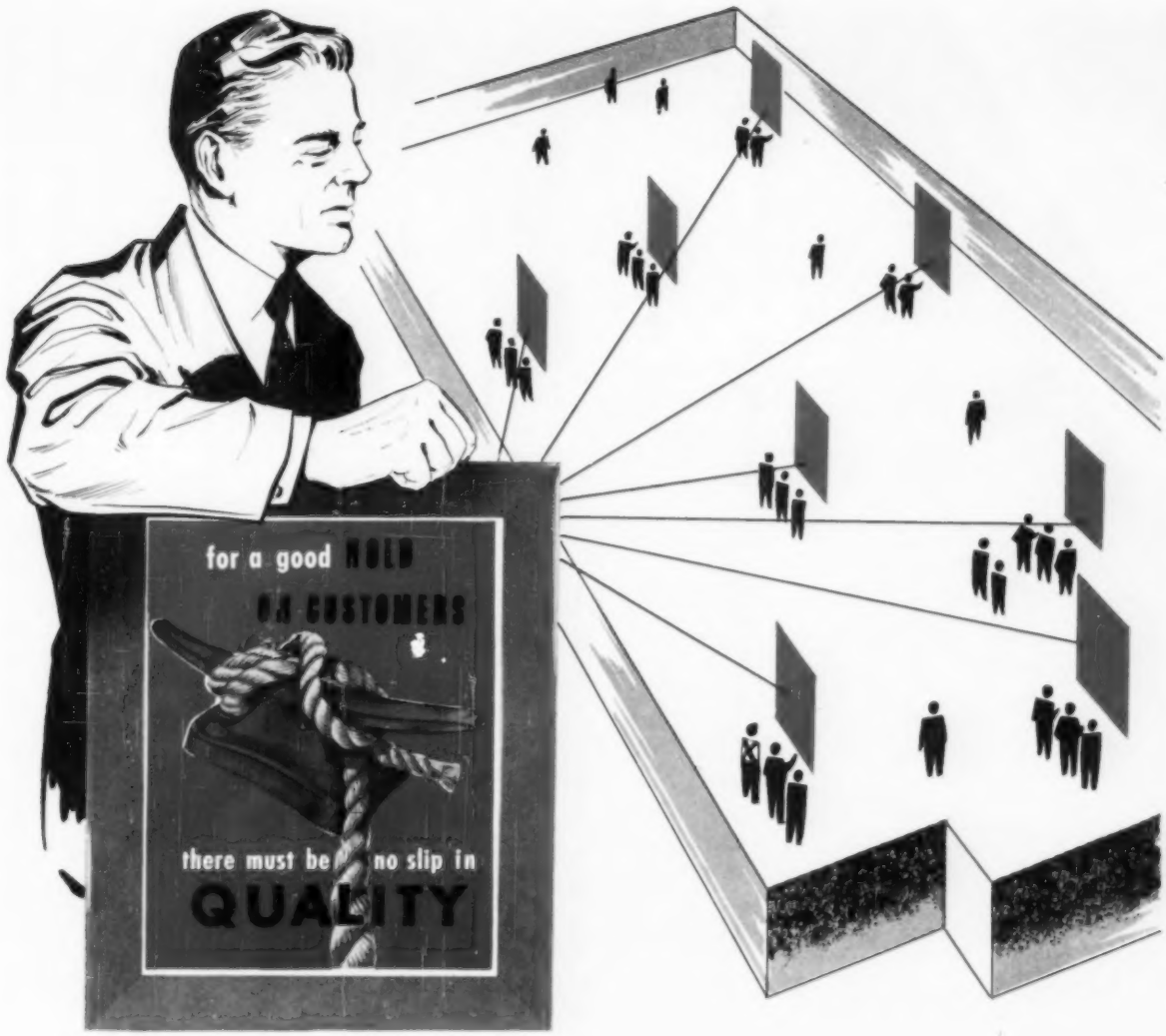
The Kingston-Brockville sub-section announced the appointment of the following officers: Peter F. Wade of the Aluminum Co., chairman; V. J. Eastcott of the DuPont Co., vice chairman; and James Martin of the Locomotive Works, secretary.

NEW HAVEN . . . On Mar. 11 R. J. D. Gillies spoke on "Operations research techniques in protection" at a dinner meeting held at the Savoy Restaurant in Hamden.

OMAHA-LINCOLN . . . Eighteen members of the section met Mar. 6 at Marchio's in Omaho to hear Glenn C. Weinhart explain and demonstrate the use of the calculator in QC and engineering statistics.

PHILADELPHIA . . . The meeting scheduled for Mar. 20 on "Preventive maintenance theory" was cancelled because of the snowstorm that welcomed spring in Philadelphia with 30 inches of snow. To be sure, it was an extreme deviation from normal.

ROCHESTER . . . The section and its sub-groups have been fortunate indeed recently to have had such lecturers as: David A. Frost, who asked "How certain are we to find the



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fly in the ointment?''; Edward A. Dubiel on ''Container specifications and vendor certification;'' R. C. Derbyshire, who discussed ''Automatic gaging'' with illustrations; Maj. Gen. Leslie E. Simon (had a bout with the flu and Charles A. Bicking pinch-hit for him) on ''Further observations on initiating a quality control group in an existing organization.''

City of Rochester, N. Y.
OFFICE OF THE MAYOR

PETER BARRY
MAYOR

PROCLAMATION

WHEREAS, on February 18, 1958, the Rochester Society for Quality Control, a Section of the American Society for Quality Control, will hold its Fourteenth Annual Quality Control Clinic in this city;

WHEREAS, attracting more than 1,000 industrialists, the Clinic will be attended by representatives from Buffalo, Syracuse, Binghamton, Corning, Cleveland, Boston, Toronto, Washington, D.C., among other cities;

WHEREAS, Quality Control has become of increasing importance as an industrial function with its aid felt in many fields of industrial endeavor;

WHEREAS, it is fitting and proper that cognizance be taken of this important occasion especially in a highly skilled industrial center such as Rochester where "Rochester made means Quality" has been a slogan and an industrial fact for many years as witnessed by the many and diversified products supplied to America and the world;

NOW, THEREFORE, I, Peter Barry, Mayor of the City of Rochester, do hereby proclaim the week beginning February 16, 1958, as "QUALITY CONTROL WEEK IN ROCHESTER", and urge industry, management, labor, and the citizens of this community to join in the observance and celebration of this important event.

Peter Barry
Mayor of Rochester, New York

February 3, 1958

The Mayor of Rochester saw fit to proclaim the week beginning Feb. 16 as ''Quality Control Week in Rochester.'' The official proclamation is reproduced above.

SAN ANTONIO . . . The Mar. 11 meeting was held at the Hilton Hotel. Prior to the start of the meeting, a cocktail party and social session was enjoyed by all. Paul E. Allen, QC and customer service manager at Beech Aircraft Corp., addressed the group on ''Quality control at Beech A/C.'' Color slides of the Beech plant products and QC methods were presented with his paper which was most informative to all.

During the third annual QC symposium held at TCU on Mar. 15 and sponsored by the Dallas-Fort Worth section, a special meeting of the program chairmen of several sections was held. Present were D. B. Tallon of the Dallas-Fort Worth section, B. M. Appleman of the South Texas section, I. R. Davis of the Waco section, and R. W. Worrick of the San Antonio section. The purpose of this meeting was to select ''Circuit'' speakers for the 1958-59 programs for each of the sections. This meeting, the first of its type, was originated by Mr. Tallon. It was a huge success and two-thirds of the program plans are now formalized. A meeting of this type may be the start of a new idea for other sections to follow.

SAN FRANCISCO BAY AREA . . . Chairman Walter Hurd recently presented a $750 check from the section to Prof. Grant Ireson, executive head of the Industrial Engineering Department of Stanford University. The money is to be used by Stanford as a tuition scholarship grant to a graduate student majoring in SQC in the Industrial Engineering Department.

The creation of the Hawaii sub-section has been announced. Carl Farden of the Pineapple Research Institute heads up the Hawaii group. Stanley Narikawa of Pearl Harbor Naval Shipyards is secretary-treasurer. There are 24 members of the group from a wide variety of industries.

The Hawaii sub-section welcomes all in the inspection, testing, or quality control fields who are actively interested

SECTION CALENDAR (MAY 20—JUNE 30)

SECTION	DATE	PLACE	TIME	SUBJECT	SPEAKER
Binghamton	May 20	Vestal American Legion Post 89	7:00 pm	Reliability as it Applies to Quality Control	Ralph E. Kuehn, IBM Corp.
Buffalo	June 2	University of Buffalo	6:30	Quality Control Problems in the Food Industry	Stanley I. Skelskie, Loblaw, Inc.
Charleston	May 20	Glass House, Knawha Airport	6:30	Annual Banquet and Ladies Night	———
Chicago	May 21	Lawson YMCA	5:00	Presentation of Winning Entries to New Ideas Contest	Contest Winners
Cincinnati	May 21	Engineering Society Bldg.	8:00	Tests of Significance in Industrial Processing	G. G. Parkin, Minnesota Mining and Mfg. Co.
	June 13	Greenhills Country Club	6:30	June Dinner Dance (combined meeting with Hamilton-Middletown section)	Installation of Officers
Columbus	June 11	Southern Hotel	6:30	Business Meeting	———
Dallas-Fort Worth	June 12	Western Hills Inn, Euless	6:00	Annual Dinner Meeting and Installation of Officers	A. C. Esenwein, Convair, Fort Worth
Evansville-Owensboro	May 20	Hotel Soaper, Henderson, Ky.	7:30	Ladies Night	———
Hamilton-Middletown	June 13	Greenhills Country Club	7:00	June Dinner Dance (combined meeting with Cincinnati section)	Installation of Officers
Hartford	May 20	Club Alden	8:00	Effects of a Firm's Organization Arrangement upon the Effectiveness of its QC Activity	Dorian Shainin, Rath & Strong
Memphis	June 6	Memphis State University	8:00	Classification of Defects	John James, Flexonics Corp.
Mid-Hudson	June 3	Germania Hall, Poughkeepsie	7:00	Social Evening	———
Montreal	June 4	Queen's Hotel	6:00	Adult Education	The Reverend Father McShane
Omaha-Lincoln	June 13	Lincoln	7:00	———	———
Scranton-Wilkes-Barre	June 10	The Deitrick, Scranton	6:30	Process Control in a Job Shop	Frank Caplan, Jr., Westinghouse Electric Corp.
Toronto	June 4	Christie's Bread	8:00	Ladies Night-Special Program and Plant Visit	———

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CHEMICAL DIVISION NEWS

The last of three Response Surface Methodology Courses will be given in Chicago on June 11-13. For details, contact H. P. Andrews, Swift & Co., U. S. Yards, Chicago, Ill. Successful courses were offered at Charlston, W. Va., and Buffalo, N. Y. earlier.

N. C. Hodge (Great Lakes Carbon Corp.), general chairman for the Second Conference of the Division to be held in Buffalo, N. Y. on Oct. 2-3, announced that all committees are staffed and the program is 90 percent complete.

in taking part in monthly meetings and in sponsoring SQC education in Hawaii.

The Hawaii sub-section is working with Dr. Harold Roberts of the University of Hawaii to arrange for an outstanding authority in the SQC field to spend the latter part of the year in Honolulu. It is intended to offer evening courses for people who are working in the quality control field and to make available consulting time for those companies actively sponsoring the course.

SCRANTON-WILKES-BARRE . . . One hundred and fifty quality control experts and their wives, representing major industries in Pennsylvania and New York, attended a joint industrial clinic at the YWCA Building in Scranton on Mar. 15. The day-long program was arranged by the section with the cooperation of the Danville-Sunbury, Allentown-Bethlehem, Binghamton, Syracuse, and Corning-Elmira sections. Comments by everyone attending rated the clinic as most successful. Chairman of the clinic was Robert Zingermann of the Scranton-Wilkes-Barre section.

Plans are to begin very shortly for the continuation of this joint industrial clinic of the six sponsoring sections. It will be held next year at the Danville-Sunbury area with perhaps another in the Syracuse area. It was felt by the joint industrial committee that two programs a year was necessary because of the growth and interest shown over the past few years. Also, this would give participating sections much better ease in handling the program, transportation, new membership, and further increase in new ideas by rotating the joint clinic to various sections of the country.

SEATTLE . . . Frank H. Squires, director of quality control for Topp Industries of Los Angeles, was guest speaker at the March meeting. Mr. Squires presented a very informative talk on "Budgets and quality control."

SOUTH TEXAS . . . The section, co-sponsored by the Texas Manufacturers Association, held its annual management night meeting on Mar. 12 at the Houston Club. August C. Esenwein, vice president and division manager of Convair Division, General Dynamics Corp., delivered a pointed message from management on "What top management expects from QC and what QC can do for top management." He emphasized the importance of reporting findings in plain language devoid of mathematical terminology. Society president Leon Bass, scheduled to deliver an address on "The nature of quality control," was unable to attend. His talk was presented by his assistant, Mr. Gant. Attendance at this meeting was unusual, as the ratio of management guests to members present exceeded one.

SOUTHERN CONNECTICUT . . . Members and guests had an enjoyable and educational evening the night of Mar. 12. A panel on quality control problems was held. The problems discussed were highly interesting as evidenced by the audience participation in the problems being resolved. John Sigman, R. T. Vanderbilt Co., filled in for A. Henry Morgan as a panel member as Henry was taken ill. M. Guy Boyd, Jr. did a terrific job as moderator as he kept the discussion active and interesting. Grover Baldwin did his usual terrific job regarding QC and its problems.

TOLEDO . . . "Automation in action" was the subject of the March meeting. A tour through the Chevrolet Passenger Transmission plant, Alexis Road, was attended by approximately 80 members and guests. Automation provides a most fertile field for SQC in obtaining desirable quality levels at minimum costs.

"Behind the scene" activity will take place during the month of June with the appointment of committees and chairmen and the laying of ground work for the 1958-59 program.

TORONTO . . . The fifth annual all-day QC forum of Mar. 8, organized by the section, was a great success. The attendance of both the lectures and the banquet was beyond expectations. All proceedings were sold at the end of the day. Guest speaker at the banquet was R. W. Todgham, president of Chrysler Corporation of Canada, Ltd. His subject—"Quality, the Vital Link"—was received very well by an enthusiastic audience that went home with much food for thought.

On Mar. 19 a successful dinner meeting was held. Apart from the section, the participants were: Guild of Accountants, Internal Auditors' Institute, Methods Time Measurement Association, Operations Research Society of Toronto, and the Systems and Procedures Association. The subject "Automation and industry's obligation to man" was ably covered by Dr. Solomon Barkin, director of research, Textile Workers Union of America.

TORONTO FIFTH ANNUAL QUALITY CONTROL FORUM

R. W. Todgham aldressed the group during the banquet at the forum. Shown above (left to right) are: Allin P. Deacon, Deacon & Associates; Dr. Brant Bonner, Dow Chemical Corp.; Mike J. O'Callaghan, section chairman; Mr. Todgham; and Bill Foskett, chairman of the forum committee.

R. J. D. Gillies, founding member of the Toronto section, is shown as he acted as moderator during the section's recent QC forum.

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TUCSON . . . Sixty-members and guests attended the April meeting which featured a panel discussion concerning cost aspects and management policies of using modern quality control techniques. Participants were P. J. Mallon, C. B. Spiteri, and R. O. Sprague of the Hughes Aircraft Company staff, with G. A. Weinshenker serving as moderator. Numerous challenging questions from the floor indicated membership interest. Among the guests was C. R. Reding, manager of the Phoenix office of the Sheffield Co. Mr. Reding was introduced by Jim Fielden of the Hughes Aircraft Company mechanical standards laboratory and presented two films on air gaging and a standards lab's activities.

WINDSOR . . . On Mar. 19 the section enjoyed a lecture on "Basic principles of statistical quality control" by John B. Pringle of the Bell Telephone Company of Canada. Many interesting demonstrations were given which were highly appreciated by section members and guests.

The Windsor section has elected the following officers for the coming year: chairman James McMillan, vice chairman Roy W. MacKay, secretary Russell C. Beemer, and treasurer George M. Smith.

SIGNIFICANT DIFFERENCES

. . . Charleston—Ed Lail, one of the organizers of the section and its present vice chairman, has been transferred by the C and P Telephone Company to New York. Charleston's loss is New York's gain and Ed will be missed in his work for the section. The executive committee appointed Bob Remke to fill the unexpired term of vice chairman.

. . . Cincinnati—The section is again honored to have the District Eight National Director elected from its roster. H. D. Birch has been selected.

. . . Cumberland—Lear T. Powell has been promoted to the position of supervisor of the SQC department of the Pittsburgh Plate Glass Company's new glass fiber plant, Works #50, at Shelbyville, Ind. Mr. Powell was formerly the assistant to the quality control supervisor at Works #7 in Cumberland.

. . . Dallas-Fort Worth—R. A. Glover of Tempco Aircraft, Dallas, was recently elected vice president of the North Texas chapter of ASA.

Dr. Paul Minton, SMU, was elected president of ASA.

. . . Evansville-Owensboro—Fifty-one people have enrolled in the first basic course in quality control offered by the section. The first session was held Feb. 26 at Central High School with Ed Shafer as the instructor.

. . . Harrisburg—In an effort to spur the enrollment of members, the section has added an incentive program. For one new member a member can enlist, a free dinner at one of our meetings is offered. For two new members, an ASQC tie bar is being offered. Since this program is in its infancy, no results are tabulated at this date.

. . . Hartford—Stanley F. Straska has been promoted from quality control engineer to supervisor of inspection for the Royal McBee Corp.

. . . Los Angeles—Gardner L. Mason, formerly director of quality control for the Turbo Division of American Machine and Foundry Co., Pacoima, has been appointed as quality control manager of Waste King Corporation's Technical Products Division in Los Angeles.

. . . New Haven—Jack Gillies has been appointed operational analysis and control engineer of the Marketing Research Department, Winchester-Western Division, Olin Mathieson Chemical Corp.

. . . Philadelphia—Stan Hart of Esterbrook Pen did a terrific job as program chairman for the Mid-Atlantic Conference held in New York during March. Many prominent speakers gave papers on various QC subjects.

. . . Rochester—David S. Greenlaw, formerly assistant director of the color technology division of the Eastman Kodak Co., has been appointed assistant technical advisor to the Kodak Park Works general manager.

. . . Tucson—Fred Emerson, assisted by Mark Manning, of Hughes Aircraft Company conducted a ten-week course in "Practical statistical quality control" after-hours at Hughes Aircraft. The course is to be repeated to accommodate the more than 300 employees who registered. Only 110 could be enrolled for the first presentation.

Our heartiest congratulations to Dale L. Lobsinger, junior past president of ASQC, who was recently honored by United Air Lines by being selected as "Man of the Year" from the 9600 people in United's Transportation Services Administration. In addition to the honor, Dale can also look forward to a two-week vacation in Hawaii, courtesy of United.

List of Short Courses in Quality Control

Usual Time Course is Held	*Type of Course*	*Where Held*	*Course Director*
February	Basic	University of Illinois, Urbana, Ill.	J. A. Henry
February	Basic	Michigan State, Lansing, Mich.	W. D. Baten
April	Basic (Graphic Arts)	New York University, New York, N. Y.	D. Macaulay
June	Basic	Marquette University, Milwaukee, Wis.	Gayle McElrath
June	Advanced	Purdue University, Lafayette, Ind.	I. W. Burr
June	Basic (Chem. Ind.)	Rochester Institute of Technology, Rochester, N. Y.	R. D. Pease
July	Basic	TAPPI Statistics Conference	M. S. Renner
July	Advanced	University of Oklahoma, Norman, Okla.	R. L. Huntington
August	Basic	University of Michigan, Ann Arbor, Mich.	C. C. Craig
August	Basic	U.C.L.A., Los Angeles, Calif.	Edward Coleman
August	Advanced	U.C.L.A., Los Angeles, Calif.	Edward Coleman
Aug.-Sept.	Basic	University of Connecticut, Storrs, Conn.	R. M. Story
September	Basic	Washington University, St. Louis, Mo.	D. J. Kaufman
September	Advanced	Rutgers University, New Brunswick, N. J.	M. E. Wescott, E. R. Ott
September	Basic	University of Mississippi, Oxford, Miss.	Gayle McElrath
October	Basic	State University of Iowa, Iowa City, Iowa	L. A. Knowler

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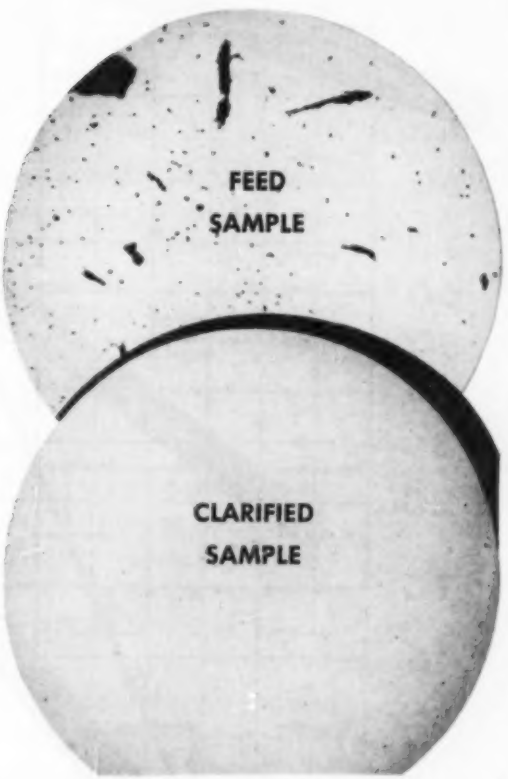

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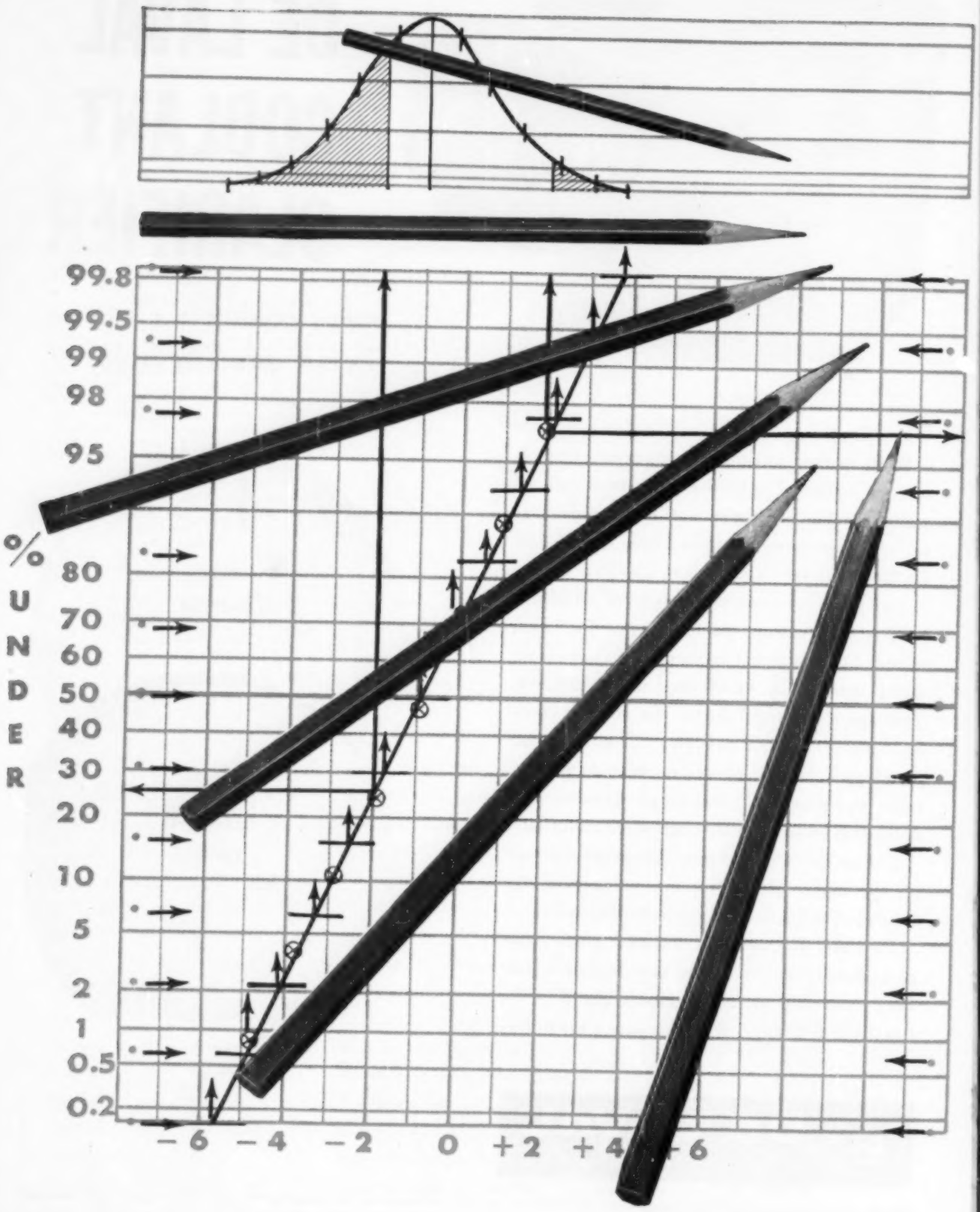
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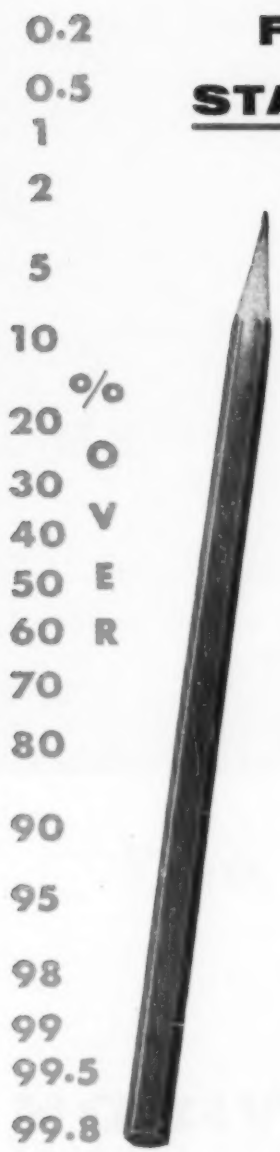

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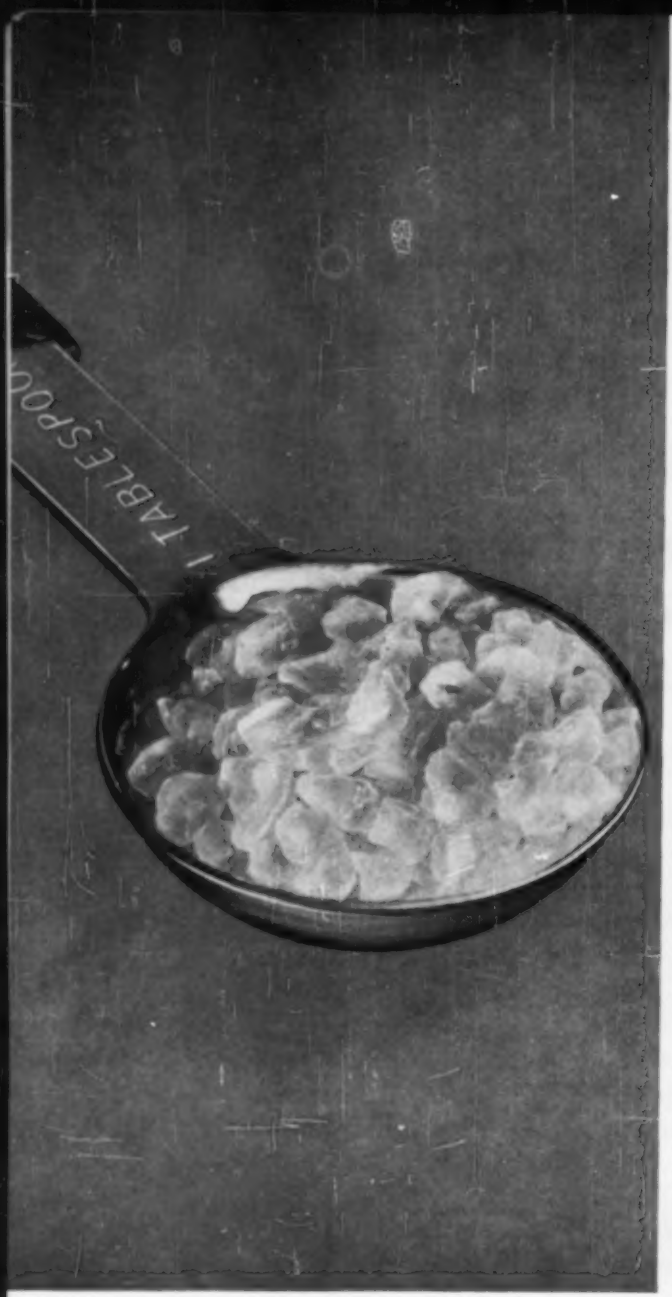

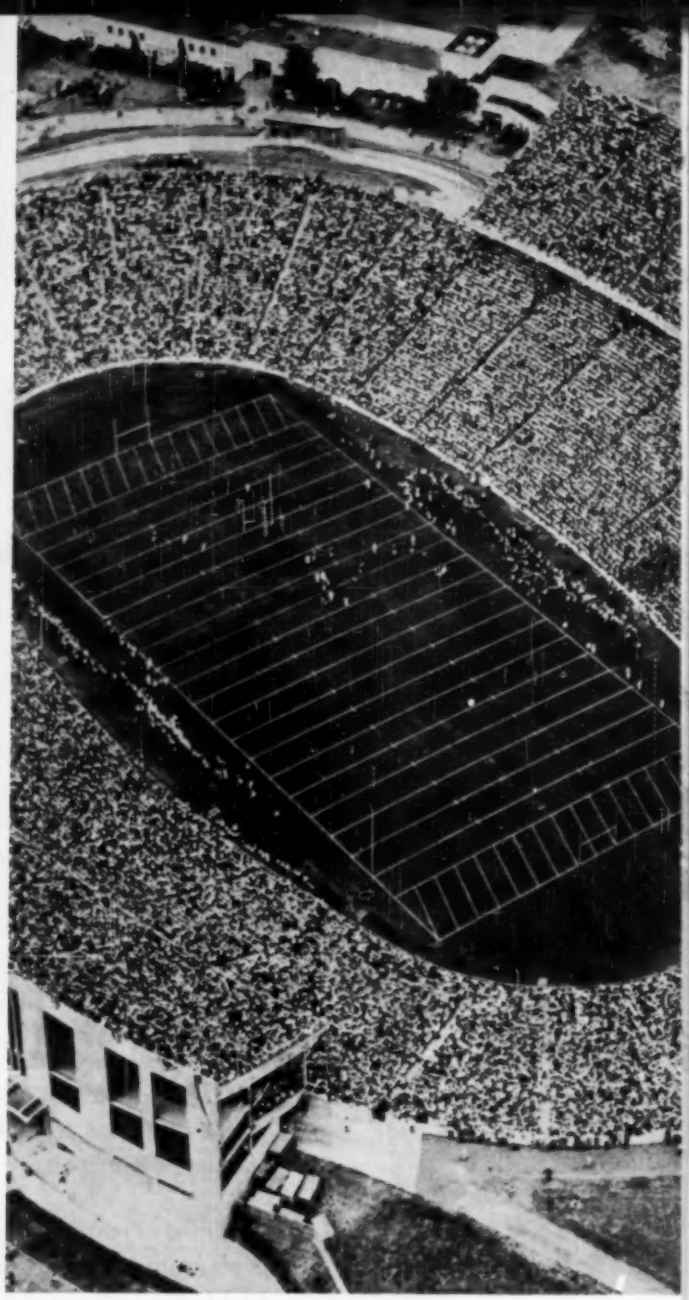

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Report of the Examining Committee

The Society takes great pleasure in congratulating the following members who have been elected to the grade of Fellow by action of the Examining Committee:

Name	Section
George M. Armour	Syracuse
Robert M. Hofstead	Syracuse
George A. Hunt	Syracuse
Carl D. Larson	Scranton-Wilkes-Barre
Robert A. Lucas	Toronto
Harry E. Robbins	Richmond, Va.

clinics, conferences, and courses

JUNE

. . . ***9-27***—Indiana Executive Development Program, Indiana University, Bloomington, Ind., sponsored by the School of Business, Indiana University, contact Thomas R. Bossort, Jr., Director, Indiana Executive Development Program, School of Business, Indiana University, Bloomington, Ind.

. . . ***11-13—Response Surface Methodology Course, Roosevelt University, Chicago, Ill., sponsored by Chemical Division, ASQC, contact Horace P. Andrews, Research Laboratories, Swift & Company, Chicago 9, Ill.***

. . . ***15-July 25***—Seventh Annual Advanced Management Seminar, University of Washington, Seattle, Wash., contact Prof. Jim Rosenzweig, Director, Advanced Management Seminar, College of Business Administration, University of Washington, Seattle 5, Wash.

. . . ***16-20***—Statistics Methods, Brevard College, Brevard, N. C., sponsored by Institute of Statistics at North Carolina State College, contact Division of College Extension, Box 5125, State College Station, Raleigh, N. C.

. . . ***16-28***—Management Course, State University of Iowa, Iowa City, Iowa, contact J. Wayne Deegan, 122 Engineering Bldg., State University of Iowa, Iowa City, Iowa.

. . . ***16-July 26***—Undergraduate and Research Seminars in Statistics, University of California, Berkeley, Calif., contact David Blackwell, Chairman of the Department of Statistics, University of California, Berkeley 4, Calif.

. . . ***17-20***—Annual Cornell University Industrial Engineering Seminars, Cornell University, Ithaca, N. Y., contact Andrew Schultz, Jr., Department of Industrial and Engineering Administration, Cornell University, Ithaca, N. Y.

. . . ***23-July 2***—15th Annual Rochester Institute of Technology "Quality Control for the Chemical Industries" Course, contact Robert D. Pease, Associate Director, Rochester Institute of Technology, 65 Plymouth Avenue South, Rochester 8, N. Y.

. . . ***30-July 11***—Short Course in Statistical Quality Control, The University of Mississippi, University, Miss., contact Department of Conferences and Institutes, University Extension, University, Miss.

JULY

. . . ***21-Aug. 1***—"Mathematical Analysis and Simulation in Industrial Operations" course, Massachusetts Institute of Technology, Cambridge, Mass., tuition $300, contact Herbert P. Galliher, program director, Operations Research Project, Massachusetts Institute of Technology, Cambridge 39, Mass.

. . . ***28-Aug. 1***—"Tolerance Management," Statistical Summer Seminar, MIT Endicott House, Dedham, Mass., contact Irving Weiss, Bell Telephone Laboratories, North Andover, Mass.

. . . ***28-Sept. 6***—Undergraduate and Research Seminars in Statistics, University of California, Berkeley, Calif., contact David Blackwell, Chairman of the Department of Statistics, University of California, Berkeley 4, Calif.

AUGUST

. . . ***4-8***—"Design of Industrial Experiments," Statistical Summer Seminar, MIT Endicott House, Dedham, Mass., contact Irving Weiss, Bell Telephone Laboratories, North Andover, Mass.

. . . ***4-22***—Industrial Reliability Course, University of California at Los Angeles, contact Prof. Edward P. Coleman, Coordinator, Industrial Reliability Course, Department of Engineering, University of California, Los Angeles 24, Calif.

. . . ***11-22—Statistical Methods in Industry Course, sponsored by the Department of Engineering of the University of California at Los Angeles and the Los Angeles section of ASQC, contact Prof. Edward P. Coleman, Coordinator, Statistical Methods in Industry Course, Department of Engineering, University of California, Los Angeles 24, Calif.***

. . . ***18-28***—11th Annual Ten-Day Quality Control by Statistical Methods Course, University of Michigan, Ann Arbor, Mich., contact Prof. C. C. Craig, 106 Rackham Bldg., Ann Arbor, Mich.

. . . ***29-Sept. 1***—Statistical Conference, University of St. Andrews, Edinburgh, Scotland, sponsored by Royal Statistical Society, contact St. Andrews Conference, Attn: Miss U. Croker, Royal Statistical Society, 21 Bentinck Street, London, W.1, England.

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a leader in the field of silicon and germanium transistors and other semiconductor products, with the largest research, engineering and manufacturing facilities in the industry, continues its planned expansion program . . . creating openings with unusual advancement potential for Quality Assurance Engineers.

Openings are in these Areas:

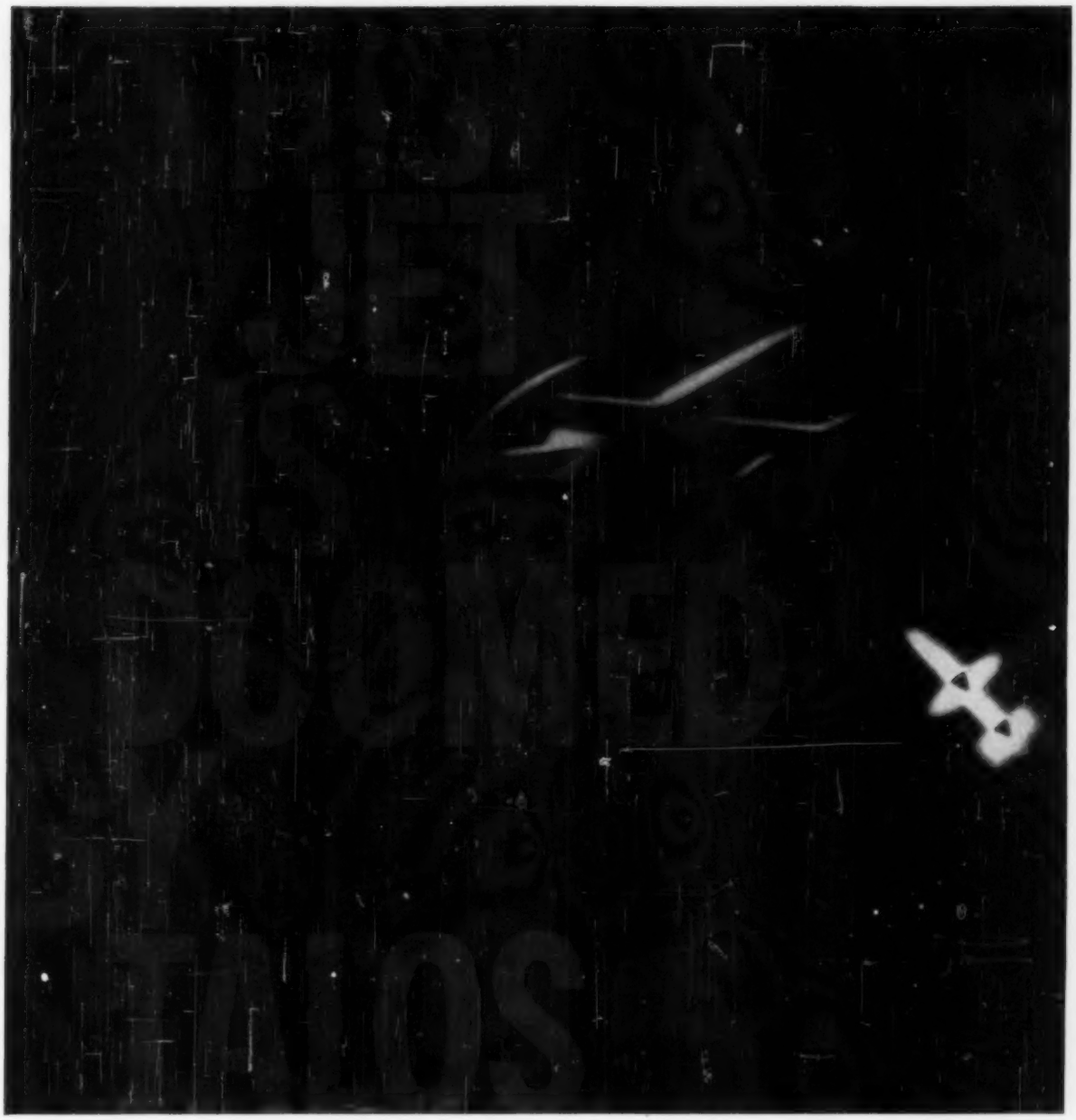
RELIABILITY ENGINEERING For reliability measurement and interpretation. To design test for evaluation. Requires broad experience as well as practical knowledge of electronic components and devices and their parameter variations. Competent to determine product capability and reliability by sampling methods. Should have degree in Physics with math background, BSEE or Statistics.

QUALITY ENGINEERING Responsible for product improvement, device development or statistical analysis. Requires strong experience in quality control engineering, preferably in an electronics industry (Semiconductor or vacuum tube). Knowledge of advanced statistics and electronics desirable. BSEE or IE.

Advance personnel policies include profit sharing, educational assistance, insurance and pension plan. You will be working in our new Semiconductor-Components Division Plant which is within Dallas and near fine residential areas, schools and churches.

Please write in confidence to Mr. H. C. Laur

SEMICONDUCTOR-COMPONENTS DIVISION
TEXAS INSTRUMENTS
INCORPORATED
5900 Lemmon Avenue — Dallas, Texas



Milliseconds after the above photograph was taken, ***TALOS*** *scored a collision hit against the F-80 jet aircraft. Fast moving, fast maneuvering* ***TALOS*** *is the supersonic surface-to-air guided missile now being added to our Navy's seagoing arsenal. As prime contractor for* ***TALOS,*** *the Guided Missile Section of the Bendix Products Division maintains the highest degree of engineering skill, quality control and reliability in the design and manufacture of* ***TALOS.*** *Opportunities are available at Bendix for qualified personnel in:* ***SYSTEMS ENGINEERING, QUALITY ENGINEERING, FIELD ENGINEERING, MANUFACTURING ENGINEERING.***

For additional information write:
Mr. E. D. McConnell, Personnel Administrator
Bendix Aviation Corporation
400-Q South Beiger Street
Mishawaka, Indiana

ACCURACY: ±.02

Picture of quality control . . . under control!

NEW MACBETH-ANSCO ELECTRONIC COLOR DENSITOMETER

Photography is an art—but the results of the final phase of this art—that all-important period in which photography becomes chemistry—can be determined with the certainty of a science . . . with an instrument such as the new Macbeth-Ansco Model 12A Densitometer. The Macbeth-Ansco can reveal the perfect color film for the perfect job . . . construct characteristic curves . . . test the quality of your developers. Through these and all of its other densitometric applications, it is your assurance of quality . . . completely controlled . . . absolutely constant.

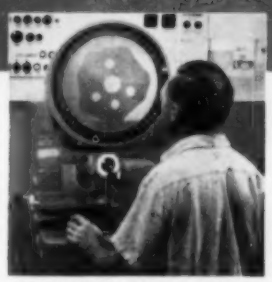
For further information, write: Ansco, Binghamton, New York. A Division of General Aniline & Film Corp

FEATURES THAT GUARANTEE CONSISTENT QUALITY

- Calibration accuracy ±.02 density over the entire range
- Measures light intensity ratios of 10,000,000 to 1
- Zeroes in red, green, blue, black and white without re-zeroing or reference
- Finger-tip filter wheel to select any color density for easier, more accurate density measurements

Ansco

Densitometry



With this Kodak Contour Projector Auburn Plastics, Inc., accurately gages a great variety of parts down to .001". Operator can easily measure angular dimensions on cams and keys, threaded mold components, center-to-center dimensions on parts and tools.

How many gages to inspect these parts?

Just one—if it's a Kodak Contour Projector.

Auburn Plastics, Inc., of Auburn, N. Y., a venerable custom molder, produces a wide variety of component parts for various manufacturers. Formerly this firm needed many mechanical gages to make necessary quality control checks.

A *Kodak Contour Projector* eliminated the expense of buying such gages—amounting in *one instance to a saving* of *$5,000.*

In a fiercely competitive business, Auburn Plastics, Inc., can submit *lower* bids because of savings permitted by *optical gaging*. The company effects additional economies by using its Kodak Contour Projector to inspect *tools* and *dies* as well as manufactured components. In all cases the projector permits gaging of angles, radii, holes and other dimensions—at a glance.

If you have an inspection problem involving myriad small parts, you can do the job easily and inexpensively with a Kodak Contour Projector. Inspection is a matter of comparing the projected image of the part with a chart gage on the screen. You inspect different types of parts simply by changing chart gages. Operators need little training.

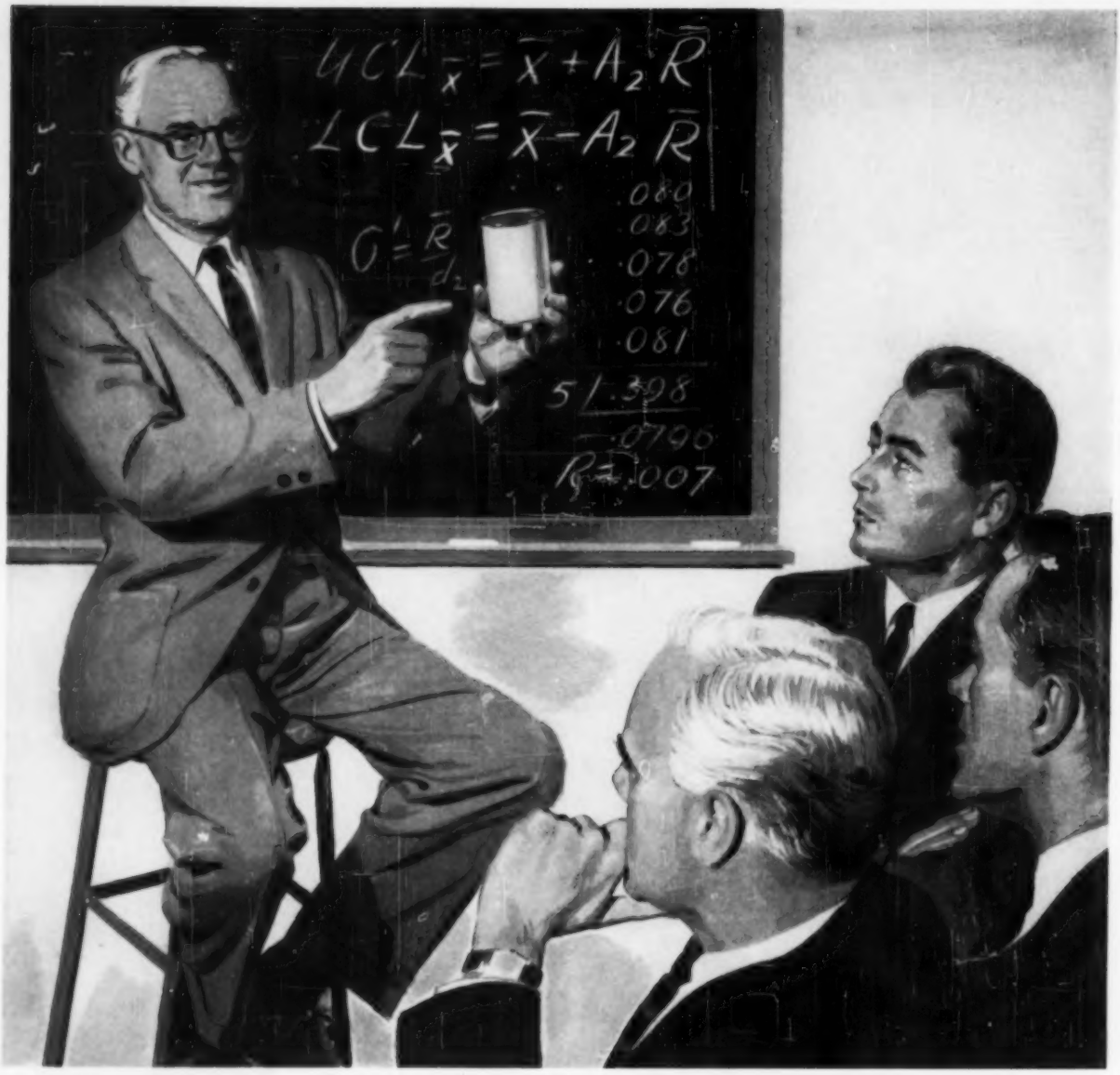
For additional information or to arrange for a demonstration of any of the 6 Kodak Contour Projector models, write to:

Apparatus and Optical Division

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the KODAK CONTOUR PROJECTOR

Kodak
TRADE MARK



The passing grade is 100!

This is a class in quality control at Continental. The instructor is explaining the basic objectives and statistical methods of quality control and their application to Continental operations. People from all levels of every Continental plant, staff positions and top management, too, attend classes like this one. It is no exaggeration to say the required grade in this course is 100. As all quality control men affirm, quality control must be applied without stinting all the way down the line, from the very smallest to the very largest operation. Our strict adherence to the principles of quality control is, we believe, one of the reasons we have been able to achieve, maintain and improve our high standards of quality through the years.

CONTINENTAL CAN COMPANY

Eastern Division: 100 East 42nd Street, New York 17
Central Division: 135 South La Salle Street, Chicago 3
Pacific Division: Russ Building, San Francisco 4
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THIS MAN HOLDS THE REINS ON A RAINBOW

Fast-growing use of colored aluminum in automotive trim and architecture imposes a dual responsibility on the men of Alcoa's Research and Development Laboratories. At the same time they create an ever-broadening color spectrum they also set up the controls necessary to ensure uniformity.

Established with the aid of the aluminum industry's finest testing facilities and translated daily into shop practice, adherence to these color control procedures makes the ten-thousandth part a mate for the first. This is industrial quality control at its best.

Your Guide to the Best in Aluminum Value

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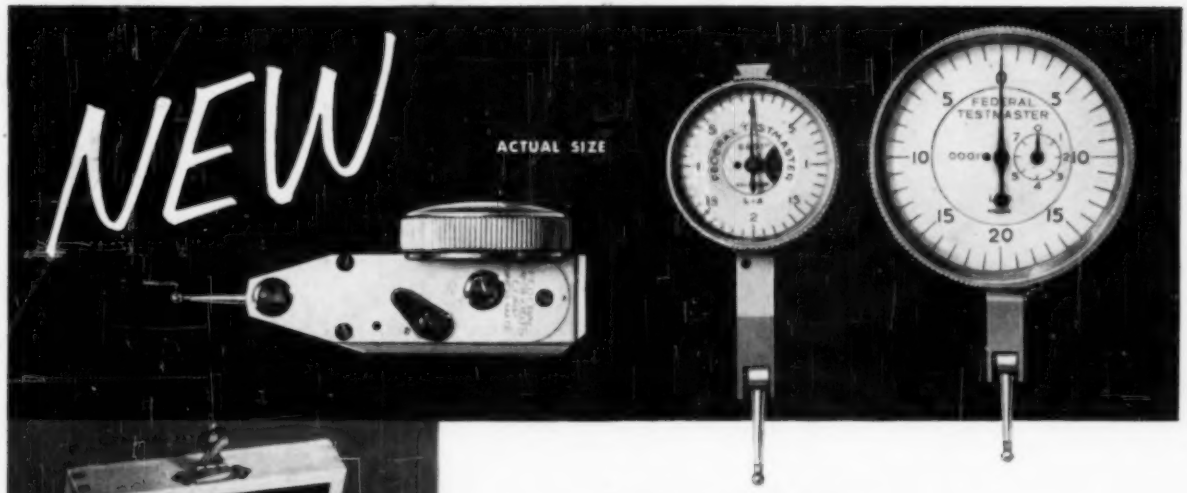
Exciting Adventure, Alternate Monday Evenings



The long range, high magnification

FEDERAL TESTMASTER

8 new models SWISS MADE to the highest FEDERAL Standards

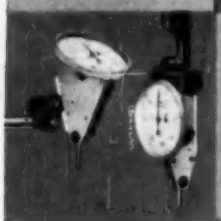
Now, the most imitated test indicator of all time . . . the Federal Testmaster, adds eight new models to its Series, all made to the highest Federal standards by Swiss craftsmen and all immediately available. These new models, too, will be imitated but never equaled. Beware of look-alikes and imitations.

- These new Federal (Series L) Testmasters have up to *four times the range* you'd expect in a test indicator. The four models with .0005" graduations have .060" range. The other four models (.0001" graduations) have .032" range.
- Despite this longer range, the new .0001" Models have at least *twice the magnification* of other type test indicators. Range per revolution is .004".
- *Even greater magnification* (50% more) if you select the large dial models in this new Testmaster series. They are available in .0001" and .0005" graduations and in regular or perpendicular styles (as are the more compact, smaller dial models).
- Many other features . . . integral dovetails for convenient and positive mounting . . . easy-to-use reversing lever . . . clutch-mounted, interchangeable contact . . . velvet-smooth operation . . . BALL BEARING PIVOTS for low-friction, truly accurate motion transfer.

FOR THE WHOLE STORY ON THESE NEW FEDERAL TESTMASTERS ASK FOR BROCHURE.

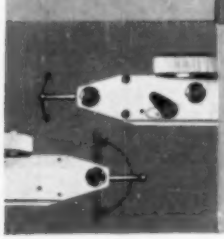
FEDERAL PRODUCTS CORPORATION
8155 **Eddy Street, Providence 1, R. I.**

INTEGRAL DOVETAILS make mounting more versatile and secure (An exclusive Federal feature).



LARGE DIAL MODELS also available in both horizontal and perpendicular styles.

EASY-TO-READ PRECISION DIALS . . . crisp, clear-cut graduations.



CLUTCH-MOUNTED CONTACT (180° rotation) and easy-to-use REVERSING LEVER.

Ask **FEDERAL** *First*

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